DTIC FILE COPY (4)

AD

Technical Memorandum 7-87

AD-A186 528

LIVE FIRE AND SIMULATOR MARKSMANSHIP PERFORMANCE WITH THE M16A1 RIFLE STUDY 1: A VALIDATION OF THE ARTIFICIAL INTELLIGENCE DIRECT FIRE WEAPONS RESEARCH TEST BED

VOLUME I: MAIN REPORT

James P. Torre
U.S. Army Human Engineering Laboratory

Jeffery L. Maxey
Advanced Technology, Inc.

Admiral S. Piper
U.S. Army Project Manager for Training Devices

DTIC
S ELECTE D
NOV 1 7 1987
CA D

March 1987
AMCMS Code 611102.74A0011

Approved for public release;
distribution is unlimited.

U.S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland 21005-5001

U.S. ARMY PROJECT MANAGER FOR TRAINING DEVICES
Orlando, Florida 32813

87 [illegible]

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO. A186528

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
LIVE FIRE AND SIMULATOR MARKSMANSHIP PERFORMANCE WITH THE M16A1 RIFLE, STUDY I: A VALIDATION OF THE ARTIFICIAL INTELLIGENCE DIRECT FIRE WEAPONS RESEARCH TEST BED, VOLUME I: MAIN REPORT

5. TYPE OF REPORT & PERIOD COVERED
Final, September 1985 - November 1986

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
James P. Torre, Jeffery L. Maxey, Admiral S. Piper

8. CONTRACT OR GRANT NUMBER(s)
N61339-85-D-0023

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Advanced Technology, Inc.
1010 Executive Center Drive, Suite 200
Orlando, Florida 32803

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS

12. REPORT DATE
March 1987

13. NUMBER OF PAGES
101

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
U.S. Army Project Manager for Training Devices
Naval Training Systems Center, Orlando, FL 32813
&
U.S. Army Human Engineering Laboratory
Aberdeen Proving Ground, Maryland 21005

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Artificial Intelligence
Direct Fire Weapons Simulator
Rifle Marksmanship, M16A1
Rifle Training (On A Simulator)
Rifle Firing, Simulator Versus Live Fire

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse side

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The Project Manager for Training Devices (PM TRADE) together with the U.S. Army Human Engineering Laboratory (USAHEL) and Naval Training Systems Center (NTSC) are developing the Artificial Intelligence Direct Fire Weapons Research Test Bed (TB) ~~to~~ examine the use of expert systems to fill roles now performed by human instructors and ~~to~~ acquire the simulation data needed for designing future training systems for direct fire weapons.

This report describes two experiments ~~that~~ show the TB is a valid research tool for determining training system requirements for future direct fire weapon systems. These experiments ~~were~~ conducted to determine if the TB would predict real-world performance. If so, it would be a valid research tool. The experiments showed that the TB simulation predicted and could support the training of live fire rifle performance.

The first experiment involved 29 infantrymen who completed three marksmanship tasks on the TB and live fire ranges. They zeroed their rifles; slow fired 10 rounds at a stationary, distinct target; and fired at E-type silhouette targets in a day defense type scenario in which targets varied in range (60 to 300 meters), speed (0 to 12 feet per second), and exposure time (2.25 to 7.25 seconds). The results indicated that TB and field performance did not differ statistically for the rounds to zero, the standard deviation of aiming accuracy for slow fire, and proportion of targets hit for the day defense scenario.

In the second experiment nine male rifle-naive college students were taught M16A1 marksmanship skills using the TB rifle simulation. These students performed in the field as well as Army trained infantrymen on the zeroing, slow fire, and defense scenario tasks.

Detailed analyses showed that the TB exhibited all of the fundamental functional relationships characteristic of man/rifle performance normally obtained in the field. These were a decline in hit probability (overall and first round) as a function of target range, exposure time, and speed.

Finally, dependent measures based on rate of firing performance differed between the TB and the field. These results indicated the need to improve the fidelity with which recoil impulse was simulated.

Because the TB and field performance were similar and did not differ statistically on the primary dependent measures for the fundamental marksmanship tasks, the conclusion was reached that the TB is a valid research tool to determine the training system requirements for future direct fire weapons systems.

AMCMS Code 611102.74A0011 Technical Memorandum 7-87

LIVE FIRE AND SIMULATOR MARKSMANSHIP PERFORMANCE WITH THE M16A1 RIFLE STUDY I: A VALIDATION OF THE ARTIFICIAL INTELLIGENCE DIRECT FIRE WEAPONS RESEARCH TEST BED

VOLUME I: MAIN REPORT

James P. Torre
U.S. Army Human Engineering Laboratory

Jeffery L. Maxey
Advanced Technology, Inc.

Admiral S. Piper
U.S. Army Project Manager for Training Devices

March 1987

APPROVED: ______________________
JOHN D. WEISZ
Director
U.S. Army Human Engineering Laboratory

APPROVED: ______________________
RICHARD J. LUNSFORD, Jr.
Colonel
Project Manager for Training Devices

Approved for public release;
distribution is unlimited.

U.S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland 21005-5001

U.S. ARMY PROJECT MANAGER FOR TRAINING DEVICES
Orlando, Florida 32813

for
CRA&I ☑
TAB ☐
nced ☐
A-1
COPY
6

PREFACE

The experiments described in this report were conducted jointly by the U.S. Army Project Manager for Training Devices (PM TRADE) and the U.S. Army Human Engineering Laboratory (USAHEL). Additionally, the Naval Training Systems Center (NTSC) supported the experiments through its Advanced Simulation Laboratory and under Contract Number N61339-82-D-0004, Task 3716-1P1, Delivery Order 0018.

Mr. Admiral S. Piper, PM TRADE, provided management and administrative support for the experiments. Mr. James P. Torre, Jr., USAHEL, defined the overall plan for the experiments to include their design, data collection protocols, and data analysis procedures. Mr. Jeffery L. Maxey, Sr., Advanced Technology, Inc., assisted in planning the experiments and was responsible for their implementation in Orlando, FL, and at Fort Benning, GA.

Mr. Albert H. Marshall (Team Leader of NTSC's Advanced Simulation Laboratory), Mr. Edward J. Purvis, Mr. Bon F. Shaw, Mr. Gary M. Bond, and Mr. Randy Field from NTSC designed, developed, and fabricated the Artificial Intelligence Direct Fire Weapons Research Test Bed. This team also configured the Test Bed and maintained it during the experiments.

The U. S. Army Infantry Board (USAIB) at Fort Benning, GA, provided the field ranges and support, arranged for the U. S. Army subjects, and collected all data required during the field portions of the experiments. In this regard the following board members were especially helpful: CPT Jose M. Hernandez, SFC Bruce E. Goble, Mr. John W. Satterthwaite, Mr. Joseph T. Green, Jr., and Ms. Iris B. Winkler.

The U. S. Marine Corps (USMC) Reserve Training Center in Orlando, FL, through its commander, CPT Thomas O'Neill, provided facilities and M16A1 rifles to support the rifle nomenclature, operation, and safety lesson portion of the experiments.

Subjects for the experiments were infantrymen provided by the 197th Infantry Brigade at Fort Benning, GA, and student volunteers enrolled in U. S. Army (USA) and U. S. Air Force (USAF) Reserve Officer Training Corps (ROTC) programs at the University of Central Florida (UCF).

This report was prepared by the Experimental Studies Team at the Orlando Office of Advanced Technology, Inc. The team leader is Mr. Jeffery L. Maxey, Sr. Team members include Mr. Jeffrey B. Cuddeback, Mr. Sander Reinhartz, Ms. Betty Salyers, Ms. Kimberley M. Smith, Charlene Kellner, and Mr. John McDonald, III.

CONTENTS: Volume I

EXECUTIVE SUMMARY 3

INTRODUCTION 9

METHOD 19

RESULTS 37

DISCUSSION AND CONCLUSIONS 95

RECOMMENDATIONS 99

REFERENCES 101

FIGURES

1. M16A1 zeroing target 13
2. Day defense scenario range layout for the parametric experiment and training experiment 14
3. Parametric experiment concept 16
4. Training experiment concept 17
5. Rules for engaging moving targets 34
6. Proportion of static targets hit as a function of range and exposure time 51
7. Proportion of moving targets hit as a function of treatment and exposure time 53
8. Proportion of moving targets hit as a function of exposure time and target range 54
9. Proportion of moving targets hit as a function of range, exposure time, and speed 55
10. Rounds fired per static target as a function of treatment, and target range 57
11. Rounds fired per static target as a function of treatment, target range and exposure time 58
12. Rounds fired per moving target as a function of group, treatment, and exposure time 60
13. Rounds fired per moving target as a function of group and target range 61
14. Rounds fired per moving target as a function of treatment, target range, and exposure time 62
15. Rounds fired per moving target as a function of exposure time and range 63
16. Rounds fired per moving target as a function of exposure time and target speed 64
17. Proportion of first round hits on static targets as a function of range and exposure time 66
18. Proportion of first round hits on moving targets as a function of range and speed 68

19. Proportion of static targets hit as a function of range and exposure time 76
20. Rounds fired per static target as a function of group, target range, and exposure time 78
21. Proportion of first round hits on static targets as a function of range and exposure time 79
22. Proportion of moving targets engaged as a function of group, target range, and target exposure time 81
23. Proportion of moving targets hit as a function of range, exposure time, and speed 82
24. Rounds fired per slow moving target as a function of group, target range, and exposure time 83
25. Rounds fired per fast moving target as a function of group, target range, and exposure time 84
26. Proportion of first round hits on moving targets as a function of range, exposure time, and speed 85

TABLES

1. Test Bed, Field, and Record Fire Correlations 40
2. Correlations Among Test Bed (TB) and Field (FD) Marksmanship Performance Measures 42
3. Measures Of Marksmanship Performance In The Test Bed and Field 44
4. Summary Of Significance Tests For Measures Of Marksmanship Performance In the Test Bed and Field 45
5. Proportion of Static Targets Engaged in Test Bed and Field 47
6. Proportion of Moving Targets Engaged in the Test Bed and Field by Target Speed, Exposure Time, and Range 48
7. Proportion of Moving Targets Engaged in the Test Bed and Field by Target Range 50
8. Proportion of Moving Targets Engaged by Target Speed and Exposure Time 50
9. Measures of Marksmanship Performance in the Test Bed and Field for the Alpha, Bravo, and ROTC Groups 69
10. Summary of Significance Tests for Zero and Self-Paced Marksmanship Performance Measures in the Test Bed and Field for the Alpha, Bravo, and ROTC Groups 71
11. Measures of Marksmanship Performance in Field by Group and Summary Significant Tests of Group Difference 72
12. F Values for Significant Main Effects and Interactions for Training Experiment Static Target Analysis 74
13. Proportion of Static Targets Engaged in the Field for the Alpha, Bravo, and ROTC Groups by Target Exposure Time and Range 75
14. F Values for Significant Main Effects and Interactions for Training Experiment Moving Target Analyses 80
15. Scales Used in Human Factors Questionnaire 87
16. Summary of Alpha and Bravo Group's Responses to the Human Factors Questionnaire 88
17. Summary of ROTC Group Responses to the Human Factors Questionnaire 90

LIVE FIRE AND SIMULATOR MARKSMANSHIP PERFORMANCE WITH THE M16A1 RIFLE
STUDY 1: A VALIDATION OF THE ARTIFICIAL INTELLIGENCE DIRECT FIRE WEAPONS RESEARCH TEST BED

EXECUTIVE SUMMARY

INTRODUCTION

The U.S. Army Project Manager For Training Devices (PM TRADE), the U.S. Army Human Engineering Laboratory (USAHEL), and the Naval Training Systems Center (NTSC) are jointly supporting development of an Artificial Intelligence Direct Fire Weapons Research Test Bed (TB). The TB will support a research program having two main objectives. The first is to determine how to design expert systems to perform teaching roles now performed by humans. The second is to acquire, through a program of experimental studies, the basic knowledge needed to design cost-efficient training systems for future line-of-sight direct fire weapons.

In order to develop the body of knowledge necessary to answer these objectives, the TB will be configured around a flexible, versatile simulation capable of manipulating training system variables associated with direct fire weapons tasks. This simulation will be the basic research tool for the TB program.

The primary thrust of the endeavors reported herein was to determine if the simulation would predict real-world performance. If so, it would be a valid research tool. Then it could be used to support a series of systematic research efforts to investigate direct fire weapons training system design issues. Examples of these issues include

- Can expert-system based instructors teach direct fire weapons skills and knowledge efficiently and effectively?
- What media are required to train the tasks needed to operate a direct fire weapons system?
- Do direct fire weapons training systems need to simulate all of the weapon design characteristics?
- To what extent does the weapon firing environment have to be simulated, e.g., noise and blast, recoil, weight transfer, etc?
- Does the target display system need to represent all potential target behaviors in its total milieu?
- How much system performance resolution is required?
- How much and what type of feedback is required?
- What are the human performance limits for system tasks?

This report describes two experiments. The first was the Parametric Experiment. The second was the Training Experiment. The Parametric Experiment was designed to evaluate the use of the TB as a valid research tool for predicting live fire man/rifle performance and to identify TB design strengths and weaknesses prior to conducting future research. The second experiment was designed to determine if the TB could be used to teach rifle marksmanship skills to rifle-inexperienced persons.

METHODOLOGY

The first TB simulation of a direct fire weapons system and its associated usage environment was the M16A1 rifle marksmanship system. This simulation consists of a terrain model board capable of representing static and moving targets at selected ranges; a demilitarized M16A1 rifle instrumented to measure aiming accuracy and simulate recoil and noise; and a microcomputer system to calculate projectile trajectories and to measure and record target impacts; and video displays to present feedback about shooter performance.

During the Parametric Experiment, 29 infantrymen were tested on three important marksmanship tasks on live fire ranges at Ft. Benning and on the TB, which was configured to represent the Fort Benning ranges.

Fifteen of the soldiers (Alpha Group) fired first in the TB and second in the field. The remaining soldiers (Bravo Group) fired first in the field and second in the TB. In each environment, the soldiers first zeroed their rifles; next slow fired 10 self-paced rounds at a zero target; and then completed a day defense scenario (twice) in which they fired at randomly presented moving (6 and 12 feet per second) and stationary E-type silhouette targets exposed for different times (3.25 to 7.25 seconds) at ranges from 60 to 300 meters (m).

Nine male college students served as test subjects for the Training Experiment. These students trained in the TB and fired in the field. The training program consisted of 4 hours of preliminary instruction (rifle nomenclature and operation, safety, firing fundamentals, and dry fire exercises) and 6 hours of TB "live" fire exercises. The preliminary instruction was completed in one 4-hour training block. The "live" fire exercises were completed over a 5-day period. During training the students zeroed the TB rifle and slow fired 10 self-paced rounds. On each training day, students were limited to a maximum of 60 minutes of practice. Additionally, the number of "live" fire trigger squeezes was kept to a maximum of 386 squeezes. This is equivalent to the number of live rounds allowed during the Army's Basic Rifle Marksmanship (BRM) program as outlined in FM 23-9, Change 3. Following the TB based training, the students moved to the field to demonstrate their marksmanship competence. Here they zeroed an M16A1 rifle; fired 10 self-paced rounds; and fired the day defense scenario twice.

DISCUSSION AND CONCLUSIONS FOR THE PARAMETRIC EXPERIMENT

Individual man/rifle marksmanship performance is highly variable.

TB performance measures predicted soldiers' individual live fire performance as well as standard Army Record Fire scores or other tests reported in the literature. Although the correlations were statistically significant, they were not high because of the high individual variability associated with man/rifle performance.

The infantryman's performance in the TB did not differ statisticallly from the field for each of the fundamental marksmanship tasks and their primary dependent measures:

- the zeroing task (using number of rounds to zero).
- the self-paced task (using SD of aiming accuracy).
- the day defense scenario (using the number of targets engaged and overall hit probability, i.e., proportion of targets hit vs targets presented).

Statistically significant differences were found between the TB and field only for dependent measures derived from an increased firing rate. These differences included

- A greater number of rounds were fired in the TB than in the field.
- First round hit probability was lower in the TB than in the field.
- More rounds were needed to obtain a first hit in the TB than in the field.
- Less time was needed to fire the first round and obtain the first hit in the TB than in the field.

Recoil and noise in the TB and field were reported as different on the human factors questionnaire.

Apparently, shooters adopted the strategy of firing more rounds at a higher rate in the TB than in the field. This was most likely because the TB recoil simulation produced a smaller muzzle deflection than is characteristic of live fire.

Detailed analyses showed that the performance of the soldiers on the TB exhibited all of the fundamental functional relationships characteristic of man/rifle performance and normally obtained in the field. These were a decline in hit probability (overall and first round) as a function of target range, exposure time, and speed.

Because TB and field performance were similar and did not differ statistically on the primary dependent measures for the fundamental marksmanship tasks, we concluded that the TB is a valid research tool to determine the training system requirements for future direct fire weapons systems.

DISCUSSION AND CONCLUSIONS FOR THE TRAINING EXPERIMENT

The ROTC students' live fire performance did not differ statistically from the infantrymen's performance for each of the fundamental marksmanship tasks and their primary dependent measures:

- the zeroing task (using number of rounds to zero).
- the self-paced task (using SD of aiming accuracy).
- the day defense scenario (using the number of targets engaged in the field and overall hit probability, i.e., proportion of targets hit versus targets presented).

The ROTC students performed in the field in much the same way as the infantrymen in the Parametric Experiment performed in the TB. For example, in the field, the students fired more rounds to achieve a first hit. They fired sooner. They had lower first round hit probabilities. The probable basis for these results is that the TB recoil effects were less than that produced by the M16A1 rifle. Because the students were trained with lesser recoil, they adopted a firing strategy that yielded these results.

It is important to note that the nine ROTC students performed in the field as well as seasoned infantrymen who had completed Basic Combat Training (BCT), Advanced Individualized Training (AIT), annual marksmanship qualification, unit marksmanship training, and a preexperiment Record Fire Course. They did so without firing a single live round of ammunition. In comparison, each soldier fires hundreds of rounds of ammunition in BCT. This suggests that the skills required to perform the primary infantryman rifle task may not require the degree of fidelity and feedback currently employed.

RECOMMENDATIONS

1. Improve the fidelity of the recoil impulse.

2. Conduct parametric experiments to define the limits of man/rifle performance as a function of practice for factors known to affect performance:

   - Firing position
   - Apparent target size
   - Trigger activation
   - Target angular rate
   - Time available to engage a target

   The ultimate goal of the experiments should be to develop a quantitative model of aiming performance as a function of practice. These data can be used as input parameter values for expert knowledge based AI training systems. It will also be used to assess future rifle systems and design.

3. Because of the cost-effectiveness implications of the finding that the TB-trained ROTC students performed as well in the field as seasoned Army riflemen, conduct an experiment to determine the bandwidth of man/rifle performance as a function of extreme levels of training system fidelity and feedback. The dependent measure should be performance from the standard Army Record Fire Qualification course. Their scores should be compared with the scores of Army soldiers completing the same course during Basic Combat Training (BCT).

LIVE FIRE AND SIMULATOR MARKSMANSHIP PERFORMANCE WITH THE M16A1 RIFLE
STUDY I: A VALIDATION OF THE ARTIFICIAL INTELLIGENCE DIRECT FIRE WEAPONS RESEARCH TEST BED

INTRODUCTION

BACKGROUND

The U.S. Army Project Manager For Training Devices (PM TRADE), the U.S. Army Human Engineering Laboratory (USAHEL), and the Naval Training Systems Center (NTSC) are jointly supporting development of an Artificial Intelligence Direct Fire Weapons Research Test Bed (TB). The TB will support a research program having two main objectives. The first is to determine how to design expert systems to perform teaching roles now performed by humans. The second is to acquire through a program of experimental studies the basic knowledge needed to design cost-efficient training systems for future line-of-sight direct fire weapons.

In order to develop the body of knowledge necessary to answer these objectives, the TB will be configured around a flexible, versatile simulation capable of manipulating training system variables associated with direct fire weapons tasks. This simulation will be the basic research tool for the TB program.

The primary thrust of the endeavors reported herein was to determine if the simulation would predict real-world performance. If so, it would be a valid research tool. Then it could be used to support a series of systematic research efforts to investigate direct fire weapons training system design issues. Examples of these issues include

- Can expert-system based instructors teach direct fire weapons skills and knowledge efficiently and effectively?
- What media are required to train the tasks needed to operate a direct fire weapons system?
- Do direct fire weapons training systems need to simulate all of the weapon design characteristics?
- To what extent does the weapon firing environment have to be simulated, e.g., noise and blast, recoil, weight transfer, etc?
- Does the target display system need to represent all potential target behaviors in its total milieu?
- How much system performance resolution is required?
- How much and what type of feedback is required?
- What are the human performance limits for system tasks?

RIFLE SIMULATION

The M16A1 rifle marksmanship system was the first direct fire weapon with its associated usage environment to be simulated in the TB. The design philosophy for developing the rifle simulation was to achieve the highest fidelity possible in representing the design characteristics of the M16A1 and its typical usage environment. Example weapon characteristics are report, recoil impulse, trajectory, and round-to-round dispersion. Example environment characteristics are target size, range, speed, and exposure time.

The highest resolution was desired for the accompanying performance measurement system. It was intended that differences of at least 150 microradians would be able to be detected by this system. The design of the shooter's performance displays was intended to provide the maximum degree of feedback for each marksmanship task. This would involve being able to display the impact points of simulated rounds relative to the target aim point for a given task.

But most importantly, the simulation design was to provide a high degree of flexibility to allow experimenters to easily manipulate important weapon, target, and training system variables to support research experimentation to determine what it takes to train soldiers to operate any direct fire weapons system.

Given this research tool, it would be possible to implement experiments to focus on a number of important, interrelated research questions for the M16:

1. How much fidelity is required to train soldiers to be proficient marksmen?
   - 1a. Does rifle report need to be simulated?
   - 1b. Does recoil impulse need to be simulated?
   - 1c. How much resolution is required in visual displays?
   - 1d. Does the introduction of weapon/ammunition dispersion inhibit or enhance the rate of learning?
2. Is performance feedback required? If so what type?
   - 2a. If required, what are the best ways to provide this feedback?
   - 2b. Is downrange feedback about projectile strike required?
3. How much practice is required?
   - 3a. What training system variables (including training device design characteristics) affect performance most?
   - 3b. What are the trade-offs among these variables?

However, before using the TB rifle simulation to support research on these questions, assurance of concordance between TB and live fire performance was required. The purpose of this report is to describe the experimental investigations that were completed to measure TB and field concordance and present the results and conclusions of these investigations including recommendatons for M16A1 near- and long-term TB research and development.

VALIDATION CONCEPT

Marksmanship Tasks

Simply stated, the TB rifle simulation was developed as a research tool to support experimentation in a number of related areas, e.g., AI system development, training system design, and weapons development. A first step in using this tool, however, was to determine if man/rifle performance in the TB was the same as performance in the real world. Important and varied rifle marksmanship tasks were therefore chosen so that the TB rifle simulation could be exercised along all of its dimensions; design strengths could be noted; and weaknesses corrected or remedied before embarking on a research program to answer research questions of interest about the M16A1 rifle.

The marksmanship tasks chosen were zeroing, slow deliberate self-paced fire, and firing a day defense scenario. Zeroing is a necessary, standardized task performed by all riflemen to make the sighting aim point coincident with the projectile impact point at the target. The target is well-defined; the range and firing position are specified; and the number of rounds needed to zero and their dispersion are measurable. Choosing this task exercised the TB's ability to measure, display, and move projectile strike as a function of changing the rifle sights in azimuth and elevation.

The self-paced firing task was chosen because it provides an opportunity to measure the shooter's maximum ability to aim as accurately as possible. This firing is performed against a distinct target from a stable position. This task thus provided a means of comparing overall firing accuracy between the TB and field.

Firing a day defense scenario provided an opportunity to parametrically examine the effects of target range, exposure time, and speed on marksmanship performance. The reason these variables were examined parametrically was to measure functional relationships in the TB and field so that performance on the TB could be dissected through the analysis of different dependent measures. In this way, design strengths and shortcomings of the rifle simulation could be identified. For example, a dependent measure such as hit probability or time to fire could be examined as a function of target range, exposure time, or speed for both the TB and live fire. These results could be compared and we could determine if discrepancies existed between TB and field performance. If differences were discovered, the probable cause could be identified through further analysis and remedies could be proposed.

In addition, the behaviors associated with this task would encompass target detection, acquisition, weapon aiming (which includes range estimation and speed to apply point of aim and/or lead rules), tracking, firing, and observing if the target was hit. In short, this task provided an opportunity to quantify the integrated act of shooting in the TB and field to determine how well the TB collectively supported these behaviors.

Validation Experiments

Two validation experiments were designed. The first was the Parametric Experiment and the second the Training Experiment. The Parametric Experiment was designed to evaluate the use of the TB to predict live fire performance of competent infantry marksmen. The Training Experiment was designed to determine if the TB could be used to teach rifle marksmanship skills to rifle-inexperienced persons.

Range requirements were identified to accommodate the implementation of the three marksmanship tasks for the two experiments. For the zeroing and self-paced tasks, the requirement was for a standard ARI zero target (see Figure 1) located 25 meters from the shooter along a clear, unobstructed line of sight. For the day defense scenario task, the requirement was for a large, flat, range with unobstructed lines of sight configured as shown in Figure 2. The following characteristics were required:

- Static and moving targets located within an 11-degree triangular sector approximately 300 meters deep and 60 meters wide at its base.
- Static targets located at 60-, 120-, 180-, 250-, and 300-meter ranges at left, center, and right positions.
- Moving targets located at 60-, 120-, and 180-meter ranges along tracks perpendicular to the center line of the range.

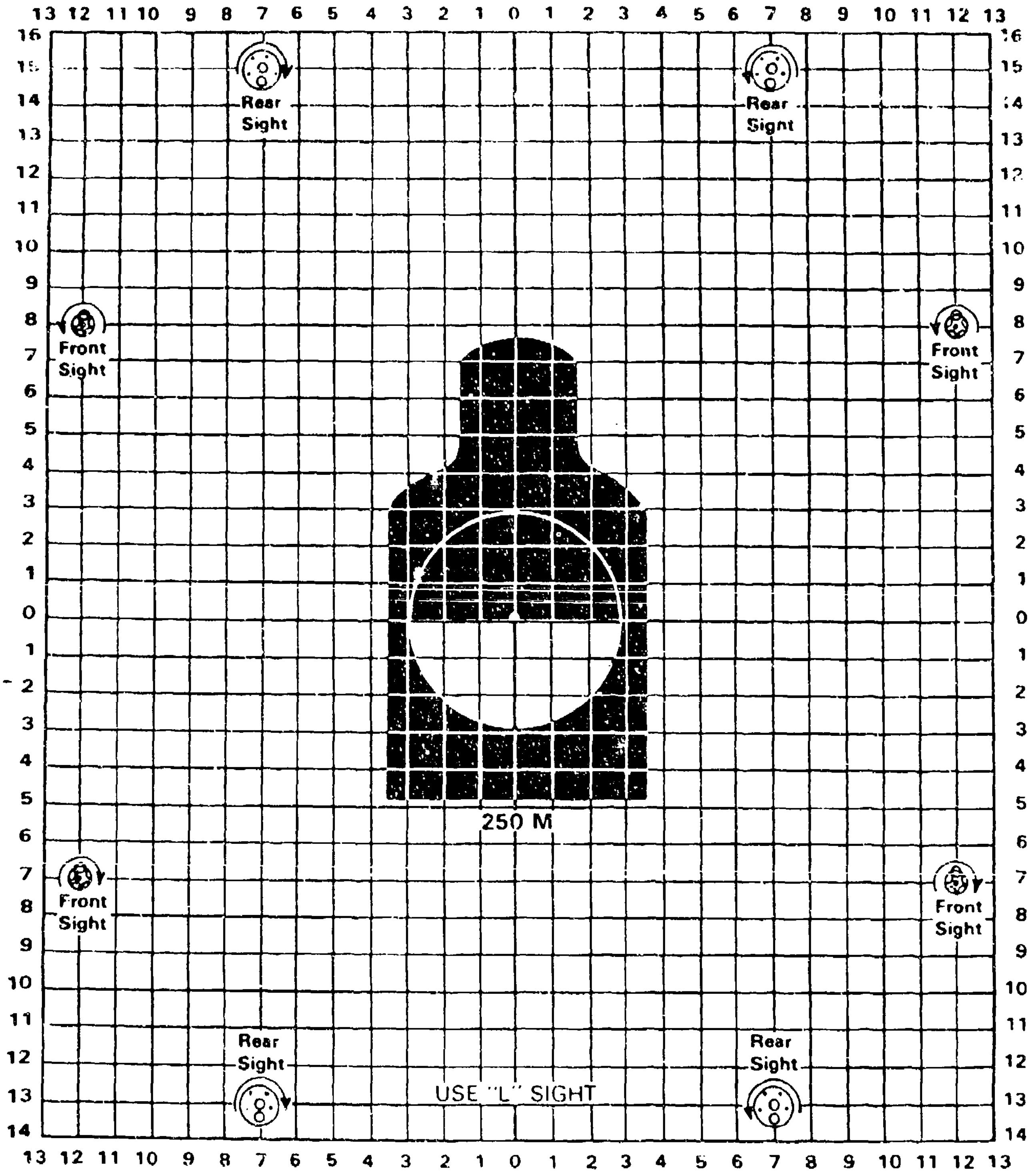
Additionally, target presentation requirements were defined for the day defense scenario. This involved systematically manipulating three primary target variables (range, exposure time, and speed) and one secondary variable (target location at a range, e.g., left [L], center [C], or right [R]).

Three target speeds were selected: 0, 6, and 12 feet per second (fps). Static (0 fps) target presentations would be at each of five ranges (60, 120, 180, 250, and 300 meters [m]) for each of three exposure times (3, 5, and 7 seconds [sec]). These targets would also be presented at each of three positions relative to the shooter (L, C, R) at each range. Combining the levels of these variables yielded 45 different static targets (see Appendix A, Volume II).

Moving (6 and 12 fps) target presentations would be only at three ranges (60, 120, and 180 m) for only two exposure times (3 and 5 sec). These presentations would be started from either a L or R position. Combining these levels yielded 24 different moving targets (see Appendix A, Volume II).

These targets, 45 static and 24 moving presentations, constituted the basic building blocks for the day defense scenario. However, in order to balance possible practice and fatigue effects across the TB and field environments as well as within subject groups, 30 random sequences of the presentations were developed. Appendix B (Volume II) describes these sequences.

25 METER ZEROING TARGET FOR M16A1 RIFLE
(WITH STANDARD SIGHTS)


13 12 11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Rear Sight
Rear Sight
Front Sight
Front Sight
250 M
Front Sight
Front Sight
Rear Sight
USE "L" SIGHT
Rear Sight

1 AIM AT TARGET CENTER ADJUST SIGHTS TO MOVE SHOT GROUP CENTER AS CLOSE AS POSSIBLE TO WHITE DOT

2 AT COMPLETION OF ZERO, ROTATE REAR SIGHT TO UNMARKED APERTURE AND WEAPON WILL BE BATTLE SIGHT ZERO FOR 250 M

Figure 1. M16A1 zeroing target.

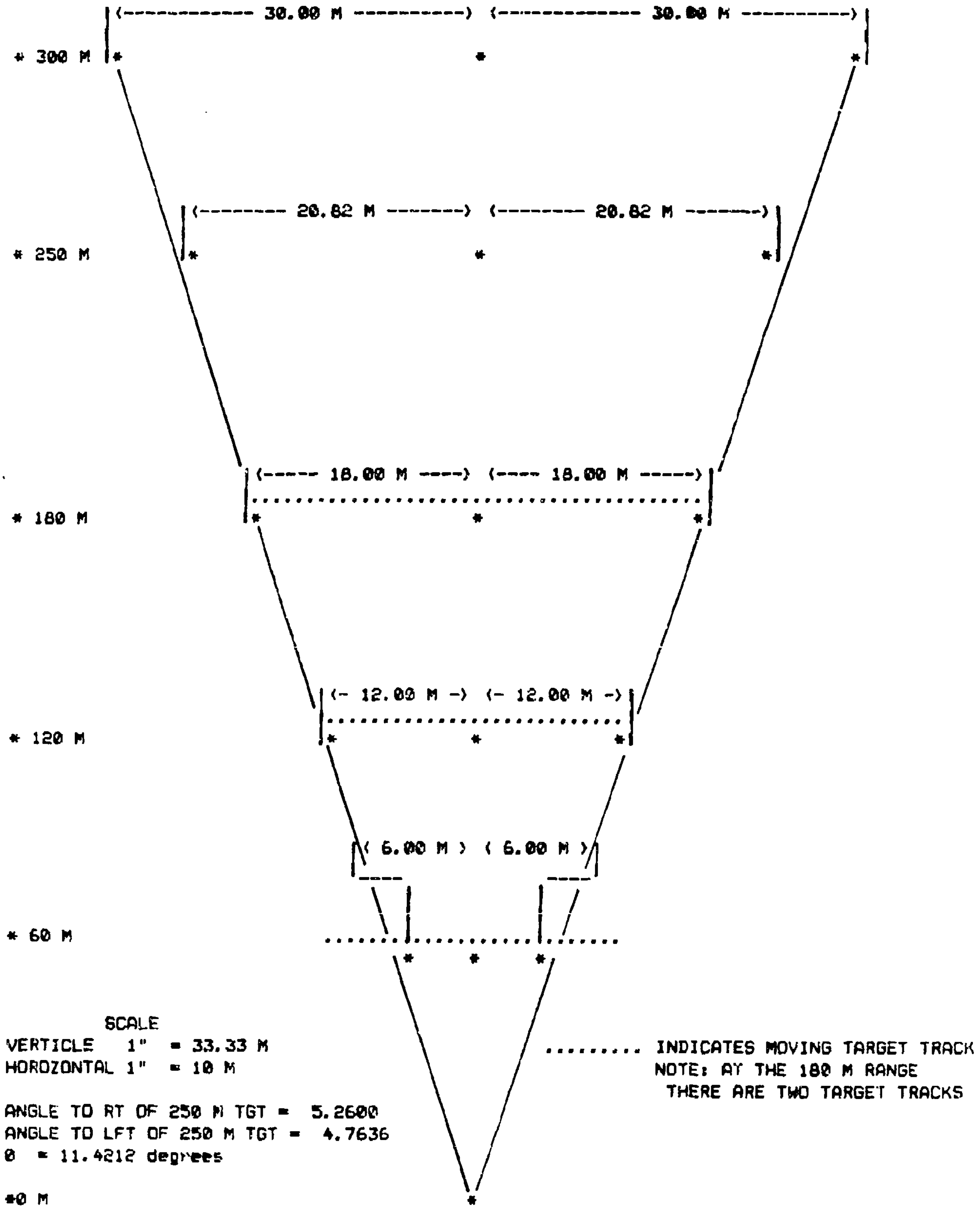

(------------ 30.00 M ----------) (------------- 30.00 M ----------)
* 300 M
(------- 20.82 M -------) (------- 20.82 M -------)
* 250 M
(----- 18.00 M ----) (---- 18.00 M -----)
* 180 M
(- 12.00 M -) (- 12.00 M -)
* 120 M
(6.00 M) (6.00 M)
* 60 M
SCALE
VERTICLE 1" = 33.33 M
HOROZONTAL 1" = 10 M
ANGLE TO RT OF 250 M TGT = 5.2600
ANGLE TO LFT OF 250 M TGT = 4.7636
0 = 11.4212 degrees
*0 M
.... INDICATES MOVING TARGET TRACK
NOTE: AT THE 180 M RANGE
THERE ARE TWO TARGET TRACKS

Figure 2. Day defense scenario range layout for the parametric experiment and training experiment.

To make the day defense scenario more combat like, the time delay between presentations was varied from 7 to 10 seconds across and within scenarios. The exact delay from one target to the next was determined by using random digits (Hodgman, 1961) to create 30 sets of delays (see Appendix C, Volume II). These were then built into the day defense scenario sequences.

Finally, test concepts for implementing the two experiments were developed. Figure 3 shows the concept for the Parametric Experiment. Prior to testing, a sample of infantrymen would zero their rifles and complete a Record Fire Qualification course. Based on the Record Fire results they would be divided into Alpha and Bravo groups. The Alpha group infantrymen would then fire the three marksmanship tasks in the TB first and in the field second. The Bravo group would fire first in the field and then in the TB. After all firing, the infantrymen would complete a human factors questionnaire designed to evaluate their firing experience in the TB and field. TB and field performance would be compared on the three tasks and functional relationships among the primary target variables for static and moving targets would be established. Based on the results of these comparisons, the determination would be made if the TB was a valid research tool for predicting live fire man/rifle performance. Also, any weaknesses in the TB would be identified and recommendations for eliminating these would be suggested.

Figure 4 shows the test concept for the Training Experiment. A sample of rifle-naive ROTC students would serve as subjects for this experiment. These students would be trained in the TB first. This would involve completing a 6-day course based on the Army's Basic Rifle Marksmanship (BRM) training program as described in FM 23-9, Change 3. This would include 4 hours of preliminary instruction (rifle nomenclature and operation, safety, firing fundamentals, and dry fire exercises) and 6 hours of TB "live" fire exercises spread over 5 days. During training, the students would complete the zero and self-paced tasks. Following the TB-based training, the students would move to the field to demonstrate their marksmanship competence. Here they would complete the zero and self-paced tasks and fire the day defense scenario task. Finally they would complete the same human factors questionnaire completed by the Parametric Experiment subjects.

Their performance in the TB and field would be compared to the performance of the Parametric Experiment subjects. Based on the results of these comparisons, the determination would be made if the TB could be used to teach rifle marksmanship skills to rifle-inexperienced persons. Also, recommendations for further training research would be made to follow up interesting and/or provocative findings.

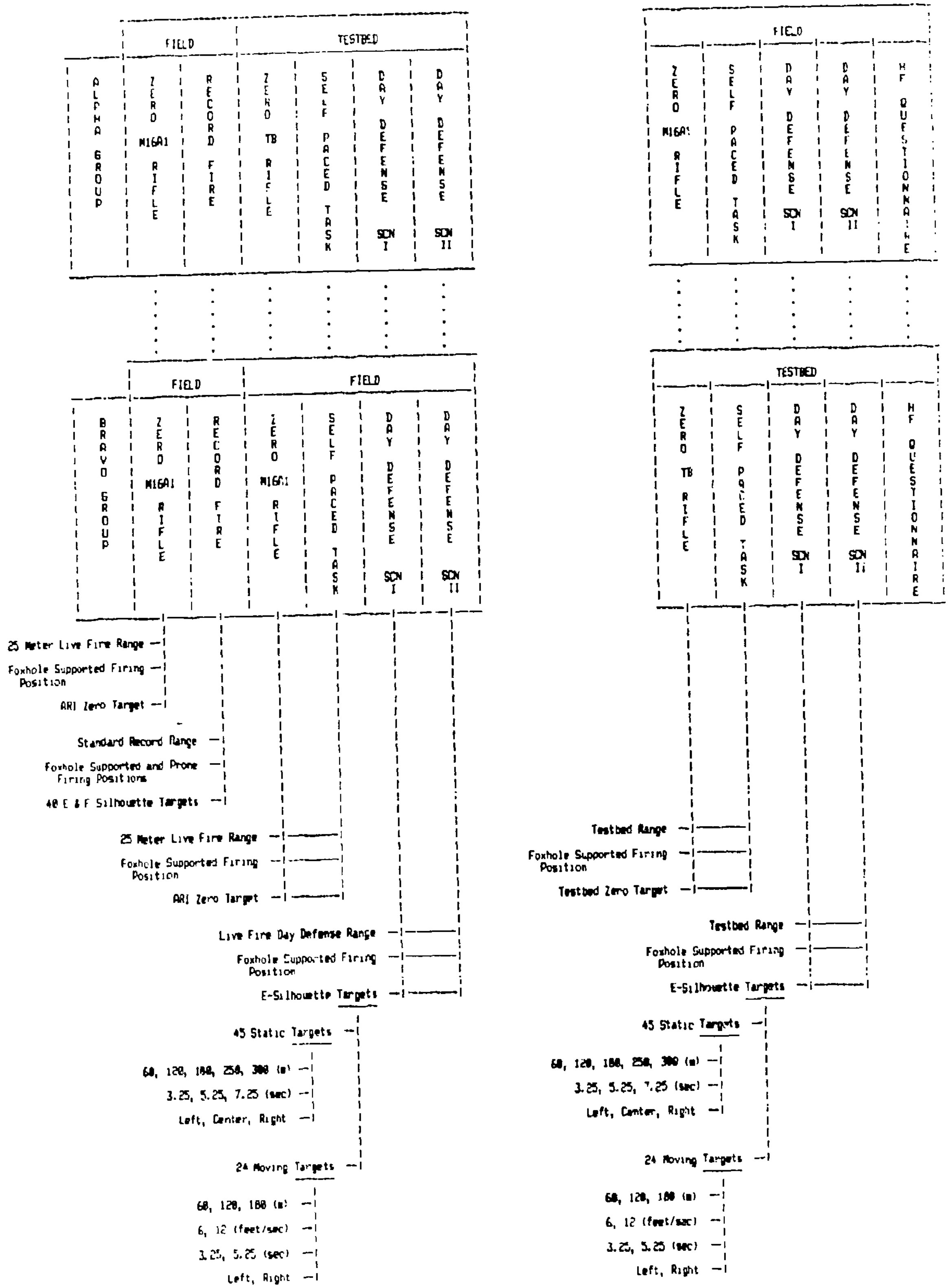

FIELD
TESTBED
ALPHA GROUP
ZERO M16A1 RIFLE
RECORD FIRE
ZERO TB RIFLE
SELF PACED TASK
DAY DEFENSE SCN I
DAY DEFENSE SCN II
FIELD
FIELD
BRAVO GROUP
ZERO M16A1 RIFLE
RECORD FIRE
ZERO M16A1 RIFLE
SELF PACED TASK
DAY DEFENSE SCN I
DAY DEFENSE SCN II
25 Meter Live Fire Range
Foxhole Supported Firing Position
ARI Zero Target
Standard Record Range
Foxhole Supported and Prone Firing Positions
40 E & F Silhouette Targets
25 Meter Live Fire Range
Foxhole Supported Firing Position
ARI Zero Target
Live Fire Day Defense Range
Foxhole Supported Firing Position
E-Silhouette Targets
45 Static Targets
60, 120, 180, 250, 300 (m)
3.25, 5.25, 7.25 (sec)
Left, Center, Right
24 Moving Targets
60, 120, 180 (m)
6, 12 (feet/sec)
3.25, 5.25 (sec)
Left, Right
FIELD
ZERO M16A1 RIFLE
SELF PACED TASK
DAY DEFENSE SCN I
DAY DEFENSE SCN II
HF QUESTIONNAIRE
TESTBED
ZERO TB RIFLE
SELF PACED TASK
DAY DEFENSE SCN I
DAY DEFENSE SCN II
HF QUESTIONNAIRE
Testbed Range
Foxhole Supported Firing Position
Testbed Zero Target
Testbed Range
Foxhole Supported Firing Position
E-Silhouette Targets
45 Static Targets
60, 120, 180, 250, 300 (m)
3.25, 5.25, 7.25 (sec)
Left, Center, Right
24 Moving Targets
60, 120, 180 (m)
6, 12 (feet/sec)
3.25, 5.25 (sec)
Left, Right

Figure 3. Parametric Experiment Concept.

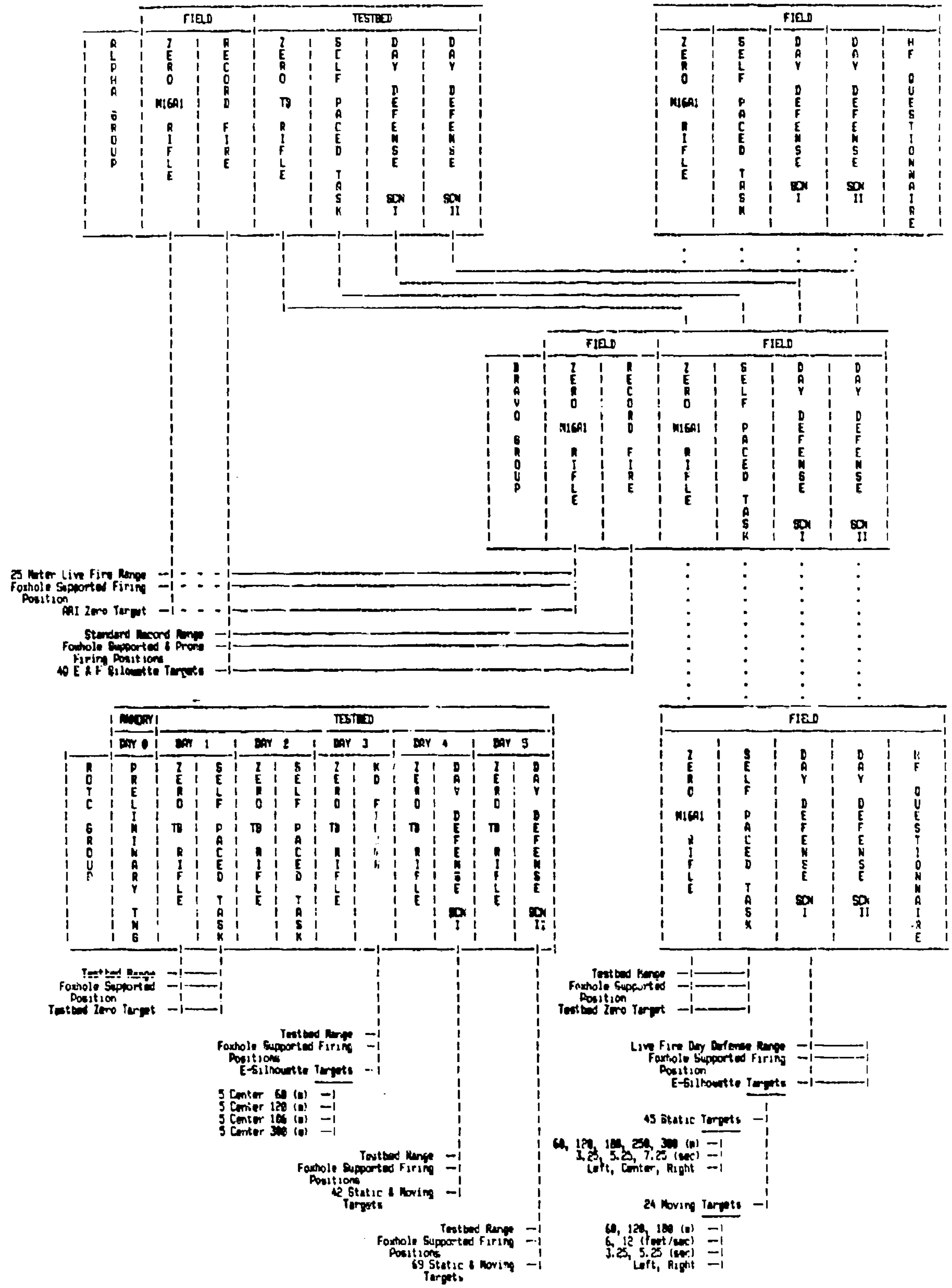

FIELD
TESTBED
ALPHA GROUP
ZERO M16A1 RIFLE
RECORD FIRE
ZERO TB RIFLE
SELF PACED TASK
DAY DEFENSE SCN I
DAY DEFENSE SCN II
FIELD
ZERO M16A1 RIFLE
SELF PACED TASK
DAY DEFENSE SCN I
DAY DEFENSE SCN II
HF QUESTIONNAIRE
FIELD
FIELD
BRAVO GROUP
ZERO M16A1 RIFLE
RECORD FIRE
ZERO M16A1 RIFLE
SELF PACED TASK
DAY DEFENSE SCN I
DAY DEFENSE SCN II
25 Meter Live Fire Range
Foxhole Supported Firing Position
ARI Zero Target
Standard Record Range
Foxhole Supported & Prone Firing Positions
40 E & F Silouette Targets
ARMORY
TESTBED
DAY 0
DAY 1
DAY 2
DAY 3
DAY 4
DAY 5
ROTC GROUP
PRELIMINARY TNG
ZERO TB RIFLE
SELF PACED TASK
ZERO TB RIFLE
SELF PACED TASK
ZERO TB RIFLE
KD FIRE
ZERO TB RIFLE
DAY DEFENSE SCN I
ZERO TB RIFLE
DAY DEFENSE SCN II
FIELD
ZERO M16A1 RIFLE
SELF PACED TASK
DAY DEFENSE SCN I
DAY DEFENSE SCN II
HF QUESTIONNAIRE
Testbed Range
Foxhole Supported Position
Testbed Zero Target
Testbed Range
Foxhole Supported Firing Positions
E-Silhouette Targets
5 Center 60 (m)
5 Center 120 (m)
5 Center 180 (m)
5 Center 300 (m)
Testbed Range
Foxhole Supported Firing Positions
42 Static & Moving Targets
Testbed Range
Foxhole Supported Firing Positions
69 Static & Moving Targets
Testbed Range
Foxhole Supported Position
Testbed Zero Target
Live Fire Day Defense Range
Foxhole Supported Firing Position
E-Silhouette Targets
45 Static Targets
60, 120, 180, 250, 300 (m)
3.25, 5.25, 7.25 (sec)
Left, Center, Right
24 Moving Targets
60, 120, 180 (m)
6, 12 (feet/sec)
3.25, 5.25 (sec)
Left, Right

Figure 4. Training Experiment Concept.

METHOD

The TB validation involved two separate but related experiments, named the Parametric Experiment and the Training Experiment. The Parametric Experiment investigated whether rifle experienced infantrymen demonstrated similar levels of marksmanship skill in the TB and on live fire ranges. The Training Experiment focused on using the TB to support rifle marksmanship training. Both were completed within the same time frame and used many of the same procedures and resources. Shared procedures and resources are described completely in the methodology for the Parametric Experiment and only briefly in the Training Experiment.

PARAMETRIC EXPERIMENT

Design

The experimental design was a mixed factorial. It included one between-subjects and one within-subjects factor. Group, the between-subjects factor, had two levels: TB first/Field second versus Field first/TB second. This factor assessed whether the order of performance measurement influenced performance.

Treatment, the within-subjects factor, also had two levels: TB versus Field. TB involved all performance measured in the TB, while Field involved all performance measured on live fire ranges. This factor assessed the effects of the TB and field environments on performance.

An Alpha equal to .01 was chosen on a priori basis to maximize the likelihood of detecting only the most powerful main effects and interactions.

Subjects and Group Matching Procedures

Thirty infantrymen from the 197th Infantry Brigade at Fort Benning, GA, served as subjects. All had completed basic rifle marksmanship (BRM) training as part of their Basic Combat Training (BCT). One soldier was unable to complete the experiment due to illness. Of the remaining 29 soldiers, 72 percent had an 11B military occupational specialty (MOS), while 28 percent had an 11C MOS.

The soldiers' ages varied from 19 to 29 years. The average age was 21 years. Sixty-nine percent had been in the Army for at least 1 year but not more than 2 years. Of the remainder, 17 percent had been in the Army for less than a year, while 14 percent had been in for 3 to 4 years. Sixty-two percent were in an E4 paygrade. Twenty-four percent were in an E3 paygrade and 14 percent were in an E2 paygrade.

Sixty-nine percent of the soldiers had a high school education, while the remaining 31 percent also had completed at least 2 years of college. Ninety percent of the soldiers had 20/20 or better vision. Ninety percent of them reported that they were good or very good Army marksmen. Twenty-four percent reported that they had had no marksmanship experience prior to joining the Army. Soldiers with prior service shooting experience rated themselves as average or above average in marksmanship ability.

Following selection for the experiment, the soldiers went to a 25-meter zeroing range where they zeroed their service rifles using the Army's standard zeroing procedures and the criterion of three successive rounds in the zeroing circle on the ARI Zero Target. Next, they moved to a Record Fire Range and fired the FM 23-9, Change 3 Qualification course (U.S. Army, 1983).

The soldiers were then divided into two groups matched on the basis of their qualification scores. Fifteen soldiers were assigned to the first (Alpha) group while 14 soldiers were assigned to the second (Bravo) group. The average qualification score for the Alpha group was 28.07 hits (SD = 6.10, N=15). The average score for the Bravo group was 27.64 hits (SD = 6.89, N = 14). A test of the difference between the two averages yielded a t = .18, df = 27. This value was not significant at the .01-level. This indicated that the matching procedure had produced two groups of soldiers that were equal in their preexperiment marksmanship ability.

Apparatus

TB Simulation. The TB simulation is described completely in Appendix D, Volume II. It has also been described by Marshall, et al. (1984). Briefly, the simulation includes a slightly sloped, untextured, green-colored terrain model board with static and moving pop-up E-type silhouette targets located at a variety of scaled ranges; a demilitarized M16A1 rifle instrumented to measure the shooter's aiming error in x and y; recoil impulse and rifle report simulation systems to provide some of the weapon effects associated with live firing; and a microcomputer system with its associated software for system control, scheduling of target presentation, presentation of shooter and experimenter feedback via CRT displays, data collection, and data storage.

TB Validation Configuration. For the experiment, the TB was configured to support the three marksmanship tasks described in the Validation Concept. A scaled E-type silhouette target similar to the silhouette shown in Figure 1 was fabricated and installed on the TB target board between the third and fourth moving target tracks for the zeroing and self-paced tasks. When observed from the shooter's station, this scaled target presented the same visual image as a full scale (40" x 20") E-type silhouette target when observed at a range of 250 meters.

To further support the zeroing and self-paced tasks, the TB software was modified to present the zeroing target in a zero or self-paced task mode. In the zero mode the shooter could fire three round groups and manually adjust the front and rear sights of the TB rifle to adjust the impact of subsequent simulated "rounds." As "rounds" were fired, their aim and impact points were displayed on the TB's RGB monitor at the experimenter's station. The coordinates of each "round" were also displayed on the alphanumeric (A/N) terminal at this station. Finally, after a group was fired, the group diameter and the number of clicks of adjustment in azimuth and elevation required to move the strike of the "round" to target center of mass were displayed on the A/N terminal. Based on this information, the experimenter could make adjustments in the TB rifle sights and continue zeroing or declare the shooter zeroed, end the zeroing task, and proceed to another task.

In the self-paced mode, the TB simulation was programmed to allow the shooter to fire 10 successive "rounds" at the zero target. As these were fired, their aim and impact points were displayed on the TB's RGB monitor while the impact point coordinates were presented on the A/N terminal. After the 10 "rounds" were fired, the diameter of the group formed by the 10 "rounds" was presented on the A/N terminal. Following task completion, the experimenter had the option of continuing with this task or proceeding to another task.

To support the day defense scenario, scaled E-type silhouette targets were fabricated and installed on the TB model board on the first, second, third, and fourth moving target tracks. When observed from the shooter's station, these targets presented the same visual images as full scale E-type targets located at 60, 120, 180, and 300 meters, respectively. Additionally, between the third and fourth moving target tracks, three static pop-up scaled 250-meter E-type targets were installed. One was placed along the target board center line, while the other two were placed to the far left and far right of the center line in accordance with the layout shown in Figure 2.

Additionally, the TB software was modified to present these targets according to the day defense scenario requirements described in the Validation Concept and summarized in Appendices A, B, and C (see Volume II). As required, the experimenter could select one of the Appendix B random scenarios for presentation. When the scenario executed, the shooter's aim and impact points for each trigger squeeze were displayed on the TB's RGB monitor. Simultaneously, an indication of whether a target hit or miss occurred was presented on the A/N terminal. At the completion of the scenario, the percentage of static and moving target hits was presented on the A/N terminal. Also at this time, the experimenter had the option of continuing with the same or another scenario or proceeding to another task.

TB Data Acquisition. The TB is designed to detect the x and y coordinates of the shooter's aim points relative to a specified target aim point, usually the center of mass. The TB ballistics simulation model takes this data, operates on it, and produces x and y strike point coordinates relative to the specified aim point. These constitute the basic performance data collected and stored by the TB computer. Ancillary data include date, time of day, and task identifier.

For the three tasks programmed for the Parametric Experiment, additional data were collected and stored by the system. For the zeroing and self-paced tasks this included the following items:

- Shot status (0 - no shot fired; 1 - target hit; 2 - target missed)
- Round Number (1st, 2nd, 3rd,.....10th)
- Group Number (1st, 2nd, 3rd,.....)

For the day defense scenario task the additional data included

- Shot status (0 - No shot fired; 1 - target hit; 2 - target missed)
- Target number (1, 2, 3, ..., 69) which uniquely identified each of the 69 targets described in Appendix A, Volume II
- Target status (1 - target up; 2 - target down)
- Percentage of static targets hit
- Percentage of moving targets hit

TB Data Display. A/N data were displayed at the TB's A/N terminal at the experimenter's station. For the validation, this consisted of the coordinates of the x and y impact points and the group diameter for the zeroing and self-paced tasks. For the day defense scenario task, an indication was also provided of whether a target was hit or missed for each round fired at it. Additionally, at the end of a scenario, the percentage of static and the percentage of moving targets hit were displayed.

X and y aim and impact points were displayed on the TB's RGB monitor. For the zeroing and self-paced task this display was programmed to show the aim and impact points relative to the center of mass on a graphic representation of the zeroing target. This representation included the 4-centimeter zeroing circle. For the day defense scenario task, the display was programmed to show the aim and impact points of each round fired at each target presented during the scenario.

Field Ranges. The field portion of the experiment was completed at Fort Benning, GA. Two ranges were used, Simpson Range and Farnsworth Range. The front part of Simpson Range is a 25-meter zeroing range while the rear part is a Record Fire Range. All live fire zeroing and self-paced firings for the experiment were completed on Simpson's zeroing range. Qualification firing for the Alpha and Bravo groups was completed on Simpson's Record Fire Range.

On the zeroing range, targets were mounted on stationary wooden frames located 25 meters from the firing point. The targets were standard ARI Zeroing Targets (see Figure 1). Only three zeroing points were used during the experiment. Each point consisted of a round concrete foxhole dug into the ground. Sandbags were used to steady the rifle during firing. A spotting scope was provided at each point to observe individual shots. This avoided the problem of having to walk downrange after each shot group was fired to observe the shooter's performance.

On the Record Fire Range, targets consisted of pop-up E-type and F-type silhouette targets. These were controlled from a tower by a range officer. Firing positions consisted of circular concrete foxholes dug into the ground with sandbags used to steady the rifle during firing.

Farnsworth Range is a U.S. Army Infantry Board (USAIB) range. During the experiment, it supported completion of the day defense scenario task. It is relatively flat and covered with short grasses. Trees and small brush define each edge. All lines of sight are unobstructed. It is about 500 meters deep and about 250 meters wide. Bleachers for observing range activities and two shelters (one housing range equipment and one housing data collection equipment) are located at the front of the range. The rear of the range ends in a berm for trapping bullets.

Targets were located on Farnsworth Range as shown in Figure 2. Static pop-up F-type silhouette targets were located at 60, 120, 180, 250, and 300 meters. Moving targets were installed at the 60-, 120-, and 180-meter ranges. All targets were protected by piles of sandbags. These piles served as a cue for locating targets.

Targets were attached to static and moving versions of the M31A1 target presentation mechanism. These in turn were connected to a central range computer. The computer was programmed to control the target presentation mechanism according to the scenario requirements for the day defense scenario, as described in the Validation Concept and summarized in Appendixes A, B, and C (see Volume II).

Farnsworth targets momentarily shorted when hit. These shorts were registered as a pulse at the range computer. When hits were sensed, the computer immediately commanded the target to fall. The hit indication, the time at which the target was instructed to rise, and the time at which it started its fall were stored by the computer on a floppy diskette. In addition, time marks produced by a sound based rifle report sensing system were recorded on the diskette to indicate the number of rounds fired during each target presentation. These data constituted the basis for determining target hits and misses, number of rounds fired per target, and time at which firings took place.

M16A1 Rifles. Three new M16A1 rifles were obtained for the field portion of the experiment. These were fired by a National Rifle Association (NRA) Master Gunner on a 25-meter range prior to the experiment to verify their operational adequacy and to produce data to measure their ballistic dispersion. Each had a measured population standard deviation of aiming accuracy of .31 of a milliradian.

Subjects were assigned one of the rifles at the start of the zeroing task in the field. This rifle was then used by them to complete all field firing tasks. This avoided the problem of having to have subjects rezero prior to each firing task.

TB and Field Comparability. In order to minimize and/or eliminate the intrusion of factors extraneous to the experiment, great care was taken to ensure the comparability of the TB and field environments. This was accomplished by equating a number of variables known to influence marksmanship performance:

- Lighting
- Target/background contrast
- Terrain configuration
- Target rise and fall times
- Target exposure time
- Shooter firing position
- Rifle/ammunition dispersion
- Rifle ballistics
- Rifle report
- Rifle recoil impulse

Lighting. The TB target board was illuminated during all data collection sessions by wall-mounted high-intensity lights. These were located above the shooter's eye level and were angled toward the board so that all targets were illuminated from the front. This arrangement caused target shadows to be cast away from the shooters. In addition, a high-intensity light was placed behind and above the shooter's position to provide adequate levels of illumination for aiming the rifle.

Prior to the experiment, illumination levels within the TB were measured with all lights activated. The levels measured were judged to be sufficient so that subjects' visual acuity would not be impaired while engaging targets.

In the field, all data collection sessions were completed under good viewing conditions. Sessions for the Parametric Experiment were conducted on sunny clear days. They usually began about 1000 hours and normally ended by 1600 hours. Sessions for the Training Experiment were conducted on slightly overcast but bright days. They started at about 1030 hours and ended about 1700 hours.

On Simpson Range, firing was along a due east azimuth. Since the sun is in the southern sky in the Fort Benning area, targets were usually lit from the sides or above early in the day and from the front later in the day. On Farnsworth Range, firing was along a southeast azimuth. This led to targets being generally backlit with shadows being cast to the shooter's left. However, in all cases, the level of illumination for targets was sufficiently high to prevent any attentuation in subject visual acuities.

Target Background Contrast. An important factor in target detectability is the contrast of the target with its surroundings. To ensure that this factor was controlled, black and white photographs of the targets on Farnsworth Range were taken. These were provided to the TB developer who then ensured that the contrast of the TB targets for comparable backgrounds matched the field targets. [illegible] was accomplished by painting the TB targets flat black and selecting the [illegible] shade of green grass for the TB target board.

Terrain Configuration. The TB target board and the field ranges are relatively flat. The TB has a slight slope to suggest distance perspective. Both environments present relatively featureless, untextured surfaces to the naked eye. All lines of sight are unobstructed.

In the field, the static and moving target mechanisms on Farnsworth Range were protected by piles of olive drab sandbags. This resulted in a row of sandbags extending from one side of the range to the other at the 60-, 120-, and 180-meter ranges. For targets located at the 250- and 300-meter ranges, this resulted in small piles of sandbags in front of the nine targets at these ranges.

To provide comparable location cues in the TB, thin strips of olive drab colored material were strung across the length of the target board in front of the second (120-meter) and third (180-meter) moving tracks. Styrofoam chips painted olive drab were glued together and placed along the first (60 meter) moving target track and at the nine target positions for the 250 and 300 meter target locations. In this way the position cues provided by the sandbags in the field were simulated on the TB target board.

Target Rise and Fall Times. In the field the target mechanisms used to present targets on Farnsworth Range had a characteristic rise time of 0.5 of a second and a fall time of 0.75 of a second. To ensure comparability with the field, the TB targets were programmed to have approximately the same rise and fall times. Subsequent measurements in the TB indicate this design goal was generally achieved, e.g., rise times were found to vary between 0.25 and 0.28 of a second and fall times between 0.57 and 0.63 of a second.

Target Exposure Time. Target exposure time has a very powerful effect on the shooter's ability to fire on and hit a target. As exposure time increases, the shooter has more opportunity to stabilize his aim and increase the likelihood of a hit. As time decreases, the shooter has less time to aim and hit probability drops off.

Exposure times in the TB and field were closely matched by first determining the actual exposure times for the field targets when programmed for 3-, 5-, and 7-second times. Next,the TB target presentation software was programmed to present the TB targets for approximately these times.

Field exposure times measured with a stopwatch were found to be about 3.25, 5.25, and 7.25 seconds for the 3-, 5-, and 7-second planned times. The TB exposure times measured with a stopwatch were also found to be approximately the same as the field times. Using a video camera to measure total exposure time (the time elapsing from when a target was first visible to when it was last visible) yielded times approximating the 3-, 5-, and 7-second times. In reporting analysis results showing the effect of the Exposure Time variable, tables and figures indicate the field exposure time measurements.

Shooter Firing Position. In the TB, the target board was inclined about 4 degrees with respect to the shooter's line of sight so that the board's rear edge was slightly higher than the front edge. The objective was to suggest distance perspective. In the field, the shooter fired from a stand that was raised about 3 feet above the ground. This yielded a viewing angle of about 1 degree with respect to the ground at 150 meters. At 60 meters this was about 2.5 degrees while at 300 meters it was about 0.5 degrees.

In both the TB and field, the shooter used sandbags to rest the barrel of the rifle. This allowed firing from a foxhole-supported firing position. The shooter could add or remove bags to obtain a stable position suited to his height.

Rifle/Ammunition Dispersion. The rifle/ammunition dispersion of the rifles used in the field was 0.31 of a milliradian. To account for this factor in the TB, the same round-to-round dispersion was included in the simulation. Tests designed to evaluate the accuracy with which TB dispersion was modeled showed it to be within acceptable levels.

Rifle Ballistics. The ballistic equations used in the TB simulation were based on data for the M16A1 provided by the Army Materiel Systems Analysis Agency. Comparisons of the TB ballistic model with the results from other ballistic models indicate that the TB model is highly accurate.

Rifle Report. The M16A1 has a measured report in the neighborhood of 150-160 db. At these levels, it is possible that some damage may occur to the human ear if adequate hearing protection is not used. When attentuated by such protection, the report is reduced to 130-140 db. For the validation, the report level produced by the TB was set to a safe level of 125 db following examination and calibration of the noise generation system by personnel from the U.S. Army Aeromedical Research Laboratory at Fort Rucker, AL. The results of the examination were incorporated into the Health Hazard Assessment of the TB (see Appendix E, Volume II). This certified the TB as safe for human use and experimentation with respect to auditory and ocular hazards.

Rifle Recoil Impulse. A major consequence of the recoil impulse produced by the M16A1 rifle is to cause the barrel to climb and upset the shooter's aim. Typical muzzle climb varies between 18 and 22 milliradians. Prior to the validation, several attempts were made to measure the muzzle climb produced by the TB recoil system. We generally found that its climb was in the neighborhood of the levels associated with firing the M16A1 rifle. However, this was only for the rifle held in an offhand or otherwise unsupported position. When firing from a position that restricted the upward movement of the rifle, we found that some reduction occurred in the observed muzzle climb. However, for the purposes of the validation, the recoil impulse was initially judged to be adequate.

Independent Variables

The major variables manipulated during the experiment were

- Group (Alpha vs Bravo)
- Treatment (TB vs Field)

In addition, the following primary target variables were manipulated during the day defense scenario task:

- Range (60, 120, 180, 250, and 300 meters)
- Exposure Time (3, 5, and 7 seconds)
- Speed (0, 6, and 12 feet per second)

Dependent Variables

Performance on the zeroing task was measured by the number of rounds required to zero the rifle.

Self-paced firing performance was measured by the diameter (covering circle) of the 10-round group, the standard deviation of aiming accuracy, and the number of hits on the zero target silhouette.

Scenario firing performance dependent measures were proportion of targets engaged, proportion of targets hit, number of rounds fired, and proportion of first round hits. Also, rate of firing performance measures was assessed. These included time to fire the first round, time to first hit, and number of rounds to first hit.

Subjects also completed a human factors questionnaire designed to determine their perception of the TB firing experience relative to the live firing portions of the experiments. This questionnaire focused on the following areas:

- Weapon operation
- Weapon recoil
- Weapon noise
- Assuming a firing position
- Aiming the rifle
- Detecting TB targets

- Hitting TB targets
- TB lighting
- Performing the self-paced task
- TB target characteristics
- Performing the zeroing task
- Performing the scenario task

Additionally, the questionnaire solicited the subjects' opinions on how well they performed in the TB relative to the field, what they liked the most and the least about the TB, and what they thought would improve the TB. This questionnaire is provided in Appendix F, Volume II.

Procedure

The Alpha group began the experiment by performing the three marksmanship tasks in the TB. Then, they completed the tasks in the field. The Bravo group performed the marksmanship tasks first in the field. Next, they completed these tasks in the TB.

Zero The Rifle. This task was completed first. It required them to fire a succession of three round groups at a zeroing target. The foxhole-supported firing position was used in both the TB and field. In the field, the subjects were able to place their elbows on the ground outside the foxhole for this task. In the TB they had no support for their elbows for this task.

The Army's procedure for zeroing (U.S. Army, 1983) was used during this task. It involved the following steps:

(a) Subjects were instructed to move to the firing point, adjust the rear sight to the long range position, and assume a foxhole-supported firing position. In the TB, the rifle was unloaded and the selector lever was in the SEMI position. Initially in the TB, subjects started with the lever in the SAFE position. As the experiment progressed, movement of the lever between SAFE and SEMI began to cause rifle failures. To eliminate this problem, the selector lever was maintained on SEMI for the remainder of the experiment. In the field, the rifle was unloaded and the lever was on SAFE prior to firing.

(b) Next, the subjects were instructed to insert a loaded magazine into the rifle. In the TB the magazine was electronically loaded with 30 rounds. In the field, magazines were loaded with 3 to 9 rounds depending on how far along subjects were in zeroing. For initial groups three to six rounds were loaded. For later groups up to 9 rounds were loaded. Subjects were instructed to fire a three-round group. In the TB, subjects aimed the rifle and fired until the group was completed. In the field, subjects were told first to chamber a round, place the selector lever in the SEMI position, and then to fire. Subjects fired until the group was completed.

(c) After firing, subjects in the TB waited for the group to be analyzed; for required data to be copied onto the subject's data record; and for the system to indicate it was ready for the subject to fire the next group. In the field, subjects waited until a data collector annotated a data collection form to describe the location of the shot group rounds; analyzed the group; and provided rounds for firing the next group.

After firing a group, subjects were shown

(a) Where the rounds had impacted

(b) Whether the group fit within a 4 cm circle

(c) The sight changes required to move the center of the group to coincide with the target aim point

Additionally, in the TB, subjects were allowed to observe the TB's RGB monitor to determine how their aim points compared with the target impact points. This allowed them to gauge the effect of dispersion on their shot groups. In the field, no comparable capability existed since only impact points registered on targets.

Sight changes were made when the group had a diameter of 4 centimeters or fewer. Changes were made by data collectors in both the TB and field. Firing continued until a 4 centimeter or smaller group (centered around the zero target's center) was fired. Suggestions were made to subjects between groups on how to decrease group's diameter.

Fire The Self-Paced Task. This required subjects to slow fire 10 rounds at their own pace. The target was the target used for the zeroing task. In the TB and the field, this task was performed immediately after the zeroing task from the foxhole-supported firing position. In the field, the subjects placed their elbows on the ground outside the foxhole for this task. In the TB, they had no support for their elbows.

During task performance, no feedback about round impacts was provided to subjects. However, after the task was completed, subjects were allowed to see how well they had done. In the TB this involved letting subjects look at the TB's RGB monitor. In the field, this involved having subjects walk downrange to retrieve and inspect the self-paced target.

Fire The Day Defense Scenario Task. This involved having subjects fire a 69-target day defense scenario twice. Only one target was presented at a time. Firing was from the the foxhole-supported position in the TB and field. In both of these environments, the subjects' elbows were unsupported.

During the scenario, the only performance feedback provided to subjects was their observation of the targets as they fell. Because of the varying exposure times, subjects could not be sure if a target fell because it was hit or because it had timed out. Additionally, no verbal feedback was provided during the task. In the TB, the TB's RGB monitor was covered so subjects could not observe it.

The following procedure was used for this task:

(a) Subjects were instructed to move to the firing point and assume a foxhole-supported firing position.

(b) Subjects were instructed to verify that the rear sight was in the battlesight position. If it was not, they were told to change it to this position.

(c) Next, subjects were briefed on the range to include a demonstration of its operation and the locations of all targets.

(d) Subjects were told to hit the targets as quickly and as often as possible. They were told to fire as many rounds as necessary to cause a target to fall. They were also told to use the foxhole-supported position for static targets and the modified foxhole-supported position for moving targets. The modified position allowed the subjects to shift their bodies to the left or right to track targets.

(e) Next, subjects were instructed to insert a full 30-round magazine in the rifle and were given an opportunity to ask any questions to clarify anything not understood When the experimenter determined that all instructions had been understood, the subjects in the TB were instructed to fire as soon as the first target was detected. In the field, the subjects were instructed to chamber a round, place the selector lever on SEMI, and fire as soon as the first target was detected.

At this point, the first scenario was activated. After every third target, the scenario paused automatically. When this happened, the subjects were given a new, fully loaded magazine to replace the one in the rifle. Following the magazine exchange, the scenario was restarted. This process continued until all targets in the scenario were presented. When this occurred, subjects were told to cease fire. In the TB they placed the rifle in its holder. In the field they placed the selector lever on SAFE and secured the rifle.

The subjects then left the firing point for a rest break. In the TB, they had a 10-minute break, while in the field they had a 30-minute break. Following the break, subjects returned to the firing point and repeated the scenario task using a different random order. The procedure for the second firing was the same as for the first.

TRAINING EXPERIMENT

Design

The design for this experiment involved a single between-subjects factor, Group, with three levels: ROTC Group, Alpha Group, and Bravo Group. This factor assessed the effect of training history (as reflected by group membership) on marksmanship skill.

Subjects in the ROTC group were chosen so that they had limited or no prior marksmanship training experience. Thus their skill in field firing could only be derived from their TB training experience. Subjects in the Alpha and Bravo groups were the infantrymen from the Parametric Experiment.

An Alpha equal to 0.01 was chosen to assess the significance of group differences. Like the Parametric Experiment, the rationale was to maximize the likelihood that only practical differences among the groups would be detected.

Subjects

Nine male students enrolled at the University of Central Florida (UCF) volunteered for this experiment. Students were advised of the nature of the experiment and completed consent forms indicating their understanding of the experimental activities. (See Appendix G, Volume II).

Three were in the USA ROTC program while six were in the USAF program. They ranged in age from 18 to 22 years. Five had been in college for at least eight semesters. Of the remainder, one had been in for three semesters and three had been in for one semester. One was in a postgraduate status, three were seniors, one was a junior, two were sophomores,and two were freshmen. Five of the students had a scientific/technical major, two had a business-oriented major, and two were undecided.

Seven of the students had a 4.00 average in their ROTC programs. Of the others, one had a 3.75 ROTC average and one had a 2.00 average. Their school grade point averages (GPA) ranged from 2.0 to 3.4. The average was 2.73. Eight of the students reported that they had average or above average vision. One student indicated below average vision but that corrective lenses were worn to remedy this.

Six of the nine students reported that they had fired a rifle, shotgun, or hand gun at least once. The other students in the sample reported that they had never fired any type of projectile weapon. All of the students indicated that they had never completed a formal or informal course in marksmanship to include the M16A1 rifle. All of the students considered themselves inexperienced shooters.

Apparatus

The TB rifle simulation described in the Parametric Experiment was used to support all marksmanship training. The field ranges described in the Parametric Experiment were used to support all posttraining field firing.

Independent Variables

The main independent variable evaluated during this experiment was training history as reflected by group membership. TB and field performance were compared as a function of group membership for all comparable data points for the zeroing and self-paced firing tasks. For the scenario task, the effects of target range, speed, and exposure time on field performance were evaluated.

Dependent Measures

The dependent measures for this experiment were the same as for the Parametric Experiment. Additionally, after all field firing was completed, the ROTC students completed the same human factors questionnaire (Appendix D, Volume II) completed by the infantrymen during the Parametric Experiment.

Procedure

The ROTC group completed marksmanship training first, then field firing at Fort Benning, GA. Marksmanship training consisted of four hours of preliminary instruction (rifle nomenclature and operation, safety, firing fundamentals, and dry fire exercises) and 6 hours of TB "live fire" exercises. The preliminary instruction was completed in one 4-hour training block. The "live fire" exercises were completed over a 5-day period. During training the students zeroed the TB rifle and slow-fired 10 self-paced rounds. They also fired a known distance task and day defense scenario tasks. On each training day students were limited to a maximum of 60 minutes of practice. Additionally, the number of "live fire" trigger squeezes was kept to a maximum of 386 squeezes. This is equivalent to the number of live rounds allowed during the Army's Basic Rifle Marksmanship (BRM) program as outlined in FM 23-9, Change 3 (U.S. Army, 1983). Following the TB based training, the students moved to the field to demonstrate their marksmanship competence. Here they zeroed an M16A1 rifle; fired 10 self-paced rounds; and fired the day defense scenario twice.

Mechanical Training. This was the first marksmanship lesson. It was completed at the USMC Reserve Training Center on Primrose Drive in Orlando, FL. The entire ROTC group attended this session. It addressed the following topics:

- Rifle nomenclature
- Mechanical operation of the M16A1 rifle, including loading the magazine, adjusting the sights, purpose of the selector lever, clearing the rifle, and the function check.
- Rifle safety, including immediate action
- The four marksmanship fundamentals (i.e., aiming, steady hold, breathe control, and trigger control)

This training was conducted by a senior Army sergeant from the USAIB and three experienced civilian marksman. It followed the U.S Army paradigm of Lecture, Demonstration, and Practice. The Lecture and Demonstration portions of the training were provided to the ROTC group as a whole. The practice portion of the training was conducted in small groups.

The lesson began by issuing each student an unloaded M16A1 rifle and magazine from the reserve center's armory. Next, the training topics listed above were discussed and demonstrated. The ROTC students practiced performing the tasks as they were demonstrated.

Next, the students were broken into small groups. Each group was assigned a trainer who guided the students through the following practical exercises:

- Assuming a prone supported firing position
- The target box exercise
- The dime/washer exercise

- The M15 sighting device exercise
- The Riddle device exercise

These exercises were completed as described in FM 23-9, Change 3 (U.S. Army, 1983). Equipment for the target box, dime/washer, the M15 sighting device, and the Riddle device exercises was provided by the USAIB. Additionally, they provided several M16 sighting devices for observing the students' sight picture.

TB Training. Students signed up for two- to three-man classes which were taught between 0800 and 1800 hours each day of a 5-day training week. Each class lasted about 15 minutes. Following the classes, practical exercise sessions were completed. These usually lasted from 30 to 60 minutes.

Training was conducted by the senior Army sergeant from the USAIB and the experienced civilian marksman. The Army sergeant monitored the practical exercises completed by each student while the civilian marksman taught the lessons supporting the exercises and explained the exercise procedures. TB training involved the following lessons:

- Monday: Zeroing the rifle
- Tuesday: Firing the self-paced task
- Wednesday: Firing at known distance targets
- Thursday: Firing at moving targets
- Friday: Firing a scenario task

Zeroing Lesson. This lesson involved an explanation of the reason for zeroing the rifle, the rationale for the U.S. Army's 250 meter battlesight, the physics of a projectile in flight, and the standard U.S. Army procedure for zeroing. Additionally, the foxhole-supported firing position was introduced and demonstrated. This material was supplemented with a discussion of the four marksmanship fundamentals and with hand drawn charts covering the lesson material. After the students' questions had been answered, a zeroing exercise was completed. This exercise used the procedures for the Parametric Experiment zero task.

The zeroing exercise was completed by each student on each day of training following the instruction scheduled for that day. This was required since there was only one TB rifle that could be used for firing.

While firing a zeroing group, students were provided no performance feedback and were not allowed to observe the graphics monitor. However, suggestions on improving performance were given after each group. Also at this time they were allowed to view the graphics monitor to observe the location of their aiming and impact points and to determine how dispersion had affected the size of their groups.

On occasion some students' zeroing performance began to deteriorate after showing evidence of improvement, e.g., shot diameters increased after a period of decreases and aiming became erratic. In these cases the students often complained of feeling fatigued or that they were having difficulty focusing on the front sight or seeing it clearly. When this happened, the students were allowed to take a short rest for 2 or 3 minutes. Afterwards, some students quickly zeroed.

In other cases, though, the rest break did not appear to help performance. For those instances involving a zeroing lesson, students were allowed to continue firing until the time scheduled for the practice session was up. Suggestions for improving performance were made. No sight changes were made unless performance improved.

For those instances in which the primary lesson goal was something other than zeroing the rifle, a best estimate of the front and rear sight settings required to zero the rifle was made by the experimenter based on the student's performance prior to its deterioration. The sights were then adjusted and the lesson task for the day was started.

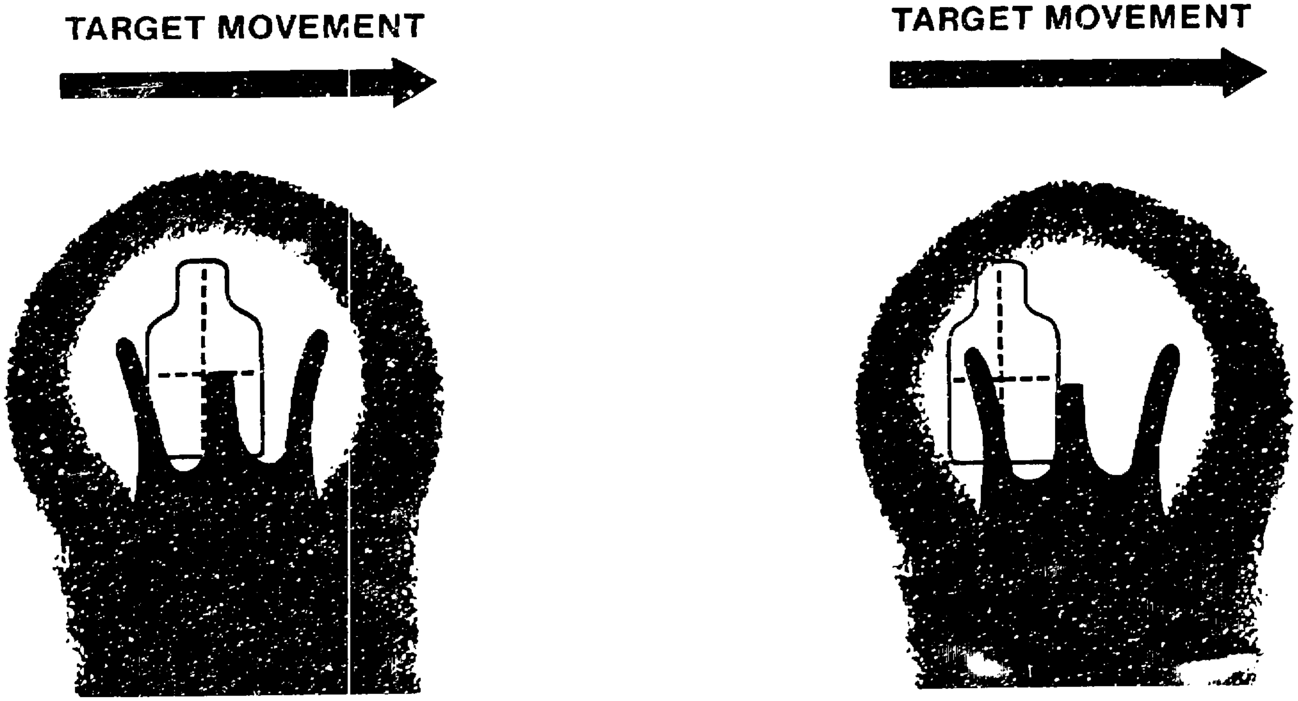
Self-Paced Lesson. The lesson for the self-paced task involved a review of the zeroing lesson material with special emphasis on the four marksmanship fundamentals. Following this, the students zeroed the TB rifle and then fired the self-paced task using the Parametric Experiment procedures. During this task the students were not allowed to observe the graphics monitor until after they had completed firing. Then they could look at the monitor and see the pattern of their rounds.

Known Distance Lesson. The Known Distance (KD) lesson involved a discussion of the effect of gravity on bullet flight and application of the hold-off technique to adjust bullet strike for ranges less than or greater than the battlesight range. Next the TB rifle was zeroed and four KD firing exercises were completed. These involved firing at E-type scaled silhouette targets. The first exercise involved firing at a 60-meter target, the second a 120-meter target, the third a 180-meter target, and the fourth a 300-meter target. The targets were always presented along the centerline of the terrain board.

Each KD exercise began by having the students fire five times at the target's center of mass. While firing the students were not allowed to see the strike of the rounds. After firing, the students were directed to observe the graphic monitor to see where their rounds impacted. It was commented to the student that due to the bullet's trajectory and the zero for the rifle, rounds fired at the center of mass would only hit in this area when the target was at or vey near the battlesight range.

Next, the students were told to fire five more rounds at the target, this time using the hold-off technique to adjust the impact points toward the center of target mass. While firing, the students were not provided any performance feedback. After firing, the student was again directed to view the monitor. The students were then critiqued on how well the hold-off technique had been applied. If a problem was apparent from the strike of the rounds, this was discussed and resolved before starting the next KD exercise.

Moving Target Lesson. This lesson involved a discussion of how to engage laterally moving targets. The students were told if the target is walking or moving very slowly at right angles to the line of sight that the best way to maximize a target hit is to place the trailing edge of the front sight post on the center of target mass (see Figure 5) and fire. The student was told that this technique would also work for a 100-meter or less running target.


TARGET MOVEMENT
TARGET MOVEMENT

FOR A WALKING TARGET OUT TO 300 METERS OR FOR A RUNNING TARGET ZERO TO 100 METERS

FOR A RUNNING TARGET 100 TO 200 METERS

Figure 5. Rules for engaging moving targets.

Next the students were told if the target is running and located between 100 and 200 meters that target hits can be maximized by placing the trailing edge of the front sight post on the leading edge of the target (see Figure 5). Finally a new firing position was introduced, the modified foxhole-supported firing position for engaging moving targets. At this point the students' questions were answered and the practical exercise for the day was discussed.

This exercise was completed immediately after the TB rifle was zeroed. It involved having the students fire a 42-round scenario involving both stationary and moving targets. All students fired the same 42 round exercise. This was defined by the first 42 trials of Scenario Random Sequence #15 (see Appendix B, Volume II). Students were allowed to fire only one round at each target. This was to keep the number of trigger squeezes during the training near the number of rounds fired during the Army's BRM program, i.e., 386 rounds. They were required to fire the exercise using the modified foxhole-supported firing position. During the exercise the students were given near real-time feedback about the strike of their rounds and whether they were providing the correct lead for moving targets.

Scenario Task Lesson. This lesson involved a brief review of all previous lessons and a detailed review of the four marksmanship fundamentals as they applied to engaging static and moving targets. Next the students were told that their practical exercise would be to complete the scenario task from the Parametric Experiment. The procedure for this task was then discussed. The procedure used in the Parametric Experiment was used in this exercise with one exception. The students were allowed to fire only one round per target. As before, this was done to keep the number of trigger squeezes during training near the number of rounds fired during the Army's BRM program.

The scenario task was completed immediately after the TB rifle was zeroed. It involved having the students fire one 69-round scenario involving both stationary and moving targets. All students fired the same exercise. This was defined by Scenario Random Sequence #30 (see Appendix B, Volume II). During the exercise the students were given near real-time feedback about the strike of their rounds and whether they were providing the correct lead for moving targets.

Field Firing. After TB training was completed, the ROTC group traveled to Fort Benning, GA. Here they went to the field ranges used in the Parametric Experiment and completed the same zeroing, self-paced, and scenario tasks that the Alpha and Bravo groups completed. The procedures for the field firing were the same as those used for the Parametric Experiment.

RESULTS

DATA PREPARATION AND ANALYSIS

The data obtained during the Parametric and Training Experiments consisted of text and numeric information recorded by data collectors or abstracted from forms completed by the shooters; computer-recorded numeric data; and live fire, paper-target data. These include the following items.

Hand-Recorded Text/Numeric Data

- Shooter's identification
- Rounds to zero in TB
- TB self-paced task group diameter
- TB self-paced task x, y aim point coordinates
- Human factors questionnaire
- Shooter background information form

Computer-Recorded Data

- Record of hits/misses and event times for TB day defense scenario
- Record of hits/misses and event times for field day defense scenario

Live Fire, Paper Target Data

- Field zero targets showing round impact points by group
- Field self-paced targets showing round impact points

Hand-recorded text/numeric data were entered into personnel computer data files for summary and analysis. The computer-recorded data were placed in ASCII character format and transferred to data files on a VAX® 11/780 computer system. These files were then processed using specially developed software to produce new data files containing the following performance measures:

- Proportion of static targets engaged per combination of Treatment, Range, and Exposure Time.

- Proportion of moving targets engaged per combination of Treatment, Range, Exposure Time, and Speed.

- Proportion of static targets hit per combination of Treatment, Range, and Exposure Time.

- Proportion of moving targets hit per combination of Treatment, Range, Exposure Time, and Speed.

- Number of rounds fired per static target combination of Treatment, Range, and Exposure Time.

- Number of rounds fired per moving target combination of Treatment, Range, Exposure Time, and Speed.

- Proportion of first-round hits per static target combination of Treatment, Range, and Exposure Time.

- Proportion of first round hits per moving target combination of Treatment, Range, Exposure Time, and Speed.

- Time to fire first round per static target combination of Treatment, Range, and Exposure Time.

- Time to fire first round per moving target combination of Treatment, Range, Exposure Time, and Speed.

- Time to first hit per static target combination of Treatment, Range, and Exposure Time.

- Time to first hit per moving target combination of Treatment, Range, and Exposure Time.

- Number of rounds to first hit per static target combination of Treatment, Range, and Exposure Time.

- Number of rounds to first hit per moving target combination of Treatment, Range, Exposure Time, and Speed.

These files were then transferred to a personal computer hard disk for analysis.

The live fire paper-target data were reviewed to determine the number of rounds fired to zero and to measure the x and y coordinates of each self-paced task impact point. Additionally, the number of bullet impacts within the zero target silhouette were counted from each target. Next, the data were entered into personnel computer data files for further summary and analysis.

The x and y coordinates of each impact point were recorded for the TB and field self-paced tasks to estimate the population standard deviation (SD) for each shooter. These coordinates were converted to mils[1]. The SDs for the x and y coordinates were then separately calculated and then combined in accordance with Grubbs (1964).

Based on the recorded x and y coordinates, the diameter of the covering circle was calculated for the TB and field self-paced tasks. These diameters were then converted to mils.

Following all data preparation activities, the TB and field zeroing, self-paced, and day defense scenario task performance measures were analyzed using programs from the BMDP Statistical Software Package for personal computers. Specific programs used were

- 1D, Simple Data Description and Data Management

- 8D, Correlations with Options for Incomplete Data

- 2V, Analysis of Variance and Covariance Including Repeated Measures.

---

[1] As used in this report 1 mil is one part in a thousand, i.e., it is the angle subtended by 1 inch over a distance of 1000 inches.

Detailed explanations of program operation and outputs are provided by Dixon, Brown, Engelman, Frane, Hill, Jennrich, and Toporek (1985).

All proportional data were analyzed with and without an arcsin transform, i.e., 2 (ARCSIN (SQRT X)). All time data were analyzed with and without a log transform, Ln (X + 1). Except as noted, analysis outcomes were the same for the transformed and untransformed data. For analyses involving within-subject variables, conservative Greenhouse-Geiser F ratios were used to evaluate the significance of main effects and interactions. This was done to allow for the possibility that covariance matrices did not meet homogeneity and compound symmetry requirements.

TB RELIABILITY AND VALIDITY

Concordance of TB and field performance was estimated by calculating reliability and validity coefficients. These were based on the TB and live fire data collected during the Parametric Experiment. Three day defense performance measures were used:

- Proportion of static targets hit
- Proportion of moving targets hit
- Proportion of static and moving targets hit

Reliabilities were calculated by correlating the first (Scenario I) and second (Scenario II) firings of the day defense task in the TB and field. Validities were calculated by combining the Scenario I and II measures within a firing environment to produce an overall score and then correlating these scores across the two environments. Additionally, TB and field performance were correlated with the Record Fire scores obtained prior to the Parametric Experiment. These correlations are reported in Table 1.

Referring to Table 1, TB and field reliabilities ranged from 0.54 to 0.67. At best, 30 to 45 percent of the variation in Scenario II performance was predicted by Scenario I performance in the TB or the field. Given the well-controlled nature of the TB and live fire tasks, these results clearly show that individual man/rifle marksmanship performance is highly variable from one firing session to the next for personnel with standard Army training backgrounds.

Validity coefficients for TB and field performance corroborate the above conclusion. These correlations were uniformly low. The overall TB/field validity was 0.36. This means that just over 10 percent of the variation in field performance was predicted by TB performance. If marksmanship performance was highly variable from one time to the next as indicated by the reliabilites, low validity coefficients would not be unexpected. This is because performance reliability places an upper limit on the size of the validity coefficient that can be obtained in a given situation (Guilford, 1956).

Using the reliability information in Table 1 and applying the correction for attentuation [2], a "true" overall TB/field validity was estimated to be 0.62.

---

[2] $$r_{\infty\omega} = \frac{r_{xy}}{\sqrt{r_{xx} r_{yy}}}$$

TABLE 1

Test Bed, Field, and Record Fire Correlations
(N = 29)

	Static Targets	Moving Targets	All
Test Bed			
Scenario I vs II	0.63 **	0.54 **	0.61 **
Field			
Scenario I vs II	0.67 **	0.54 **	0.54 **
Test Bed vs Field	0.40 *	0.15	0.36
Record Fire vs Testbed	0.54 **	0.59 **	0.61 **
Record Fire vs Field	0.30	0.26	0.30

* $p < .05$
** $p < .01$

Additional evidence supporting the conclusion that marksmanship performance is highly variable comes from examining the correlations among Record Fire, TB, and field firing performance. As shown in Table 1, TB performance predicted live fire field performance as well as Record Fire performance predicted field firing performance. In both cases, however, the prediction correlations were low in magnitude. For example, the overall TB/field firing correlation was 0.35; the Record Fire/overall field firing correlation was 0.30; and the overall TB/Record Fire correlation was 0.61. Clearly the TB, field, and Record Fire tasks measured common skills. Because the tasks were similar, TB and field performance as well as Record Fire and field performance should have correlated at much higher levels. But they did not. The failure to find high correlations among TB, field firing, and Record Fire performance can again be attributed to highly variable man/rifle performance.

Table 2 provides yet more evidence of high levels of marksmanship variability. This table presents between-task and within-task correlations among performance measures for the zeroing (Rounds to zero) and self-paced (SD of Aiming Accuracy) tasks in addition to the day defense scenario task. Inspection of Table 2 shows that TB/field firing correlations were low for the zeroing and self-paced tasks just as they were for the day defense scenario task. Additionally, correlations among the zeroing and self-paced performance measures as well as between them and the day defense performance measures and Record Fire scores were low and not significant.

The basic conclusion is inescapable. The predictive power of the TB is as good as it can be given the levels of performance variability inherent in the day defense scenario task. It predicts live fire field performance as well as standard Army Record Fire performance. The TB validities are also very similar to results obtained by other investigators in predicting rifle marksmanship performance:

- 0.61 between stationary steadiness and target scores for 73 U.S. Army marksmen (Spaeth & Dunham, 1921).
- 0.57 between stationary steadiness and rifle coach ratings of marksmanship performance for 43 college students (Humphreys, Buxton, & Tayler, 1936).
- 0.61 between slow fire and intelligence and rifle experience for 79 U.S. Army marksmen (MacCaslin & McGuigan, 1956).
- 0.67 between sustained fire and intelligence and rifle experience for 79 U.S. Army marksmen (MacCaslin & McGuigan, 1956).
- 0.68 between marksmanship proficiency scores and a battery of aptitude tests for 100 U.S. Army personnel completing Officer Candidate School (Deese, 1970).
- 0.41 to 0.66 between Record Fire qualification scores and Weaponeer marksmanship performance for 69 initial entry soldiers completing BRM training (Schendel, Heller, Finley, & Hawley, 1985).

TABLE 2

Correlations Among Test Bed (TB) and Field (FD) Marksmanship Performance Measures

Performance Measure	TB vs FD Validities	TB Intercorrelations			FD Intercorrelations		
		SD	PS	PM	SD	PS	PM
Rounds to Zero (Z)	0.27	0.40 *	0.16	0.23	0.37 *	0.02	-0.20
SD of Aiming Accuracy (SD)	0.27		0.06	0.12		0.22	0.05
Proportion of Hits on Static Targets (PS)	0.40 *			0.44 *			0.22
Proportion of Hits on Moving Targets (PM)	0.15			-			-

* Significant at $p < .05$

** Significant at $p < .01$

Performance Measure	TB Record Fire Intercorrelations	FD Record Fire Intercorrelations
Rounds to Zero (Z)	-0.17	-0.23
SD of Aiming Accuracy (SD)	0.11	-0.23
Proportion of Hits on Static Targets (PS)	0.54 **	0.30
Proportion of Hits on Moving Targets (PM)	0.48 **	0.19

** Significant at $p < .01$

Summary Analyses

Zeroing Task. Task performance was measured by the number of rounds needed to zero the rifle. Table 3 presents the means (Mns) and standard deviations (SDs) for rounds to zero for the Alpha and Bravo groups, separately and together in the TB and the field. Table 4 summarizes the results of a repeated-measurements analysis of variance for rounds to zero. Appendix H, Volume II, contains the full analysis. The main effect of Group and the Group x Treatment interaction was not significant. This indicated that the order in which data were collected did not lead to differential transfer. The Treatment main effect (TB versus field) was also not significant. This result indicated that zeroing in the TB was not any more or less difficult than zeroing in the field.

Self-Paced Task. Task performance was measured by the diameter of the 10-round group, the SD of aiming accuracy, and the number of hits on the zero target silhouette. Table 3 also presents the Mns and SDs for these measures for the Alpha and Bravo groups, separately and together, in the TB and the field. Table 4 summarizes repeated-measurement analysis of variance for the self-paced task measures. Appendix H, Volume II, presents the full set of results. None of the main effects or interactions in any analysis were significant. These results indicate that testing order did not lead to differential transfer for the self-paced task and that TB and field performance were not different.

Day Defense Scenario Task. Task Performance was measured by proportion of targets engaged, proportion of targets hit one or more times, number of rounds fired per target, and proportion of first round hits across the 2-day defense scenarios. Table 3 presents the Mns and SDs for these measures for the Alpha and Bravo groups, separately and together for the TB and the field for both static and moving targets. Table 4 summarizes repeated measurement analysis of variance for the measures. Appendix H, Volume II, contains the full set of results. None of the main effects or interactions were significant for static or moving targets for proportion of targets engaged or proportion of targets hit. These results indicate that testing order did not lead to differential transfer and that TB and field performance for these measures were not significantly different.

For rounds fired, the analysis of variance results were different.[3] For both static and moving targets, the Treatment main effect was significant. This indicated that the rounds fired per static or moving target in the TB were greater than in the field. For static targets the average was 1.88 rounds (SD = 0.56) in the TB versus 1.12 rounds (SD = 0.11) in the field. For moving targets, the average was 2.05 rounds (SD = 0.56) for the TB versus 1.55 rounds (SD = 0.21) for the field.

---

[3] Initial analyses of the TB rounds fired yielded heterogeneous group SDs for static and moving targets, Fmax = 11.44 and 15.81. Inspection of the raw data showed that two Alpha subjects fired many more rounds per target than the other subjects. Their data were removed which led to homogeneity of the group variances for the TB data, Fmax = 3.43 and 2.27.

TABLE 3
Measures Of Marksmanship Performance In The Test Bed And Field

Measure		Test Bed			Field		
		Alpha (A)	Bravo (B)	A & B	Alpha (A)	Bravo (B)	A & B
Zero Task							
	N	15	14	29	15	14	29
Rounds to Zero	Mn	32.4	24.0	28.3	30.6	28.5	29.6
	SD	12.0	21.1	17.2	20.7	19.4	19.8
Self-Paced Task							
	N	15	14	29	15	14	29
Diameter (Covering Circle) of Group (mils)	Mn	1.86	2.02	1.94	2.13	2.13	2.13
	SD	0.54	0.48	0.51	0.67	0.49	0.58
	N	15	14	29	15	14	29
SD of Aiming Accuracy (mils)	Mn	0.52	0.53	0.53	0.55	0.54	0.55
	SD	0.14	0.10	0.12	0.17	0.13	0.15
	N	15	14	29	15	14	29
Number of Hits on Target Silhouette	Mn	9.07	8.29	8.69	8.20	8.36	8.28
	SD	1.28	1.54	1.44	1.21	1.28	1.22
Day Defense Scenario							
Proportion of Targets Engaged							
	N	15	14	29	15	14	29
Static	Mn	0.928	0.939	0.933	0.912	0.929	0.920
	SD	0.052	0.048	0.05	0.039	0.044	0.042
	N	15	14	29	15	14	29
Moving	Mn	0.974	0.985	0.979	0.982	0.966	0.974
	SD	0.032	0.028	0.030	0.022	0.044	0.035
Proportion of Targets Hit							
	N	15	14	29	15	14	29
Static	Mn	0.701	0.661	0.682	0.686	0.610	0.649
	SD	0.085	0.122	0.105	0.081	0.089	0.092
	N	15	14	29	15	14	29
Moving	Mn	0.649	0.641	0.645	0.578	0.554	0.566
	SD	0.147	0.126	0.135	0.151	0.168	0.157
Number of Rounds Fired Per Target							
	N	13	14	27	13	14	27
Static	Mn	2.14	1.62	1.88	1.08	1.15	1.12
	SD	0.63	0.34	0.56	0.09	0.11	0.11
	N	13	14	27	13	14	27
Moving	Mn	2.28	1.82	2.05	1.58	1.53	1.55
	SD	0.62	0.41	0.56	0.23	0.18	0.21
Proportion of First Round Hits							
	N	15	14	29	15	14	29
Static	Mn	0.486	0.480	0.483	0.629	0.539	0.535
	SD	0.113	0.113	0.111	0.94	0.89	0.101
	N	15	14	29	15	14	29
Moving	Mn	0.367	0.415	0.390	0.453	0.463	0.458
	SD	0.116	0.123	0.120	0.132	0.171	0.149

TABLE 4

Summary Of Significance Tests For Measures Of Marksmanship Performance In The Test Bed And Field

Measure	Group (G) Alpha (A) vs Bravo (B) F	df	P	Treatment(T) Test Bed (TB) vs Field (F) F	df	P	Interaction G x T F	df	P
Zero Task									
Rounds to Zero	0.91	1,27	0.35	0.10	1,27	0.75	0.57	1,27	0.46
Self-Paced Task									
Diameter (Covering Circle) of Group (mils)	0.28	1,27	0.60	2.19	1,27	0.15	0.42	1,27	0.52
SD of Aiming Accuracy (mils)	0.01	1,27	0.91	0.40	1,27	0.53	0.45	1,27	0.82
Number of Hits on Target Silhouette	0.93	1,27	0.34	1.14	1,27	0.30	1.58	1,27	0.22
Day Defense Scenario									
Proportion of Targets Engaged									
Static	0.98	1,27	0.33	1.76	1,27	0.20	0.09	1,27	0.77
Moving	0.09	1,27	0.77	0.37	1,27	0.55	2.32	1,27	0.14
Proportion of Targets Hit									
Static	3.92	1,27	0.06	2.66	1,27	0.12	0.80	1,27	0.38
Moving	0.14	1,27	0.72	4.84	1,27	0.04	0.06	1,27	0.82
Number of Rounds Fired Per Target									
Static	5.81	1,25	0.02	54.95	1,25	0.00 **	8.27	1,25	0.01 **
Moving	4.74	1,25	0.04	26.18	1,25	0.00 **	4.48	1,25	0.04
Proportion of First Round Hits									
Static	2.60	1,27	0.12	17.69	1,27	0.00 **	3.08	1,27	0.09
Moving	4.74	1,27	0.52	7.85	1,27	0.01 **	0.65	1,27	0.43

** Significant at $p < 0.01$

While the Group main effect was not significant for static targets, the Group x Treatment interation was. In the TB, the Alpha group fired significantly more rounds than the Bravo group (Mn = 2.14 and Mn = 1.62 rounds, respectively). In the field, they fired about the same number of rounds (Mn = 1.08 and 1.15 rounds, respectively). A similar result occurred for moving targets but was not as strong, i.e., the moving target Group main effect was not significant and the Group x Treatment interaction approached significance ($p = 0.04$).

For proportion of first round hits, the analysis results were similar to those for number of rounds fired. For both static and moving targets, neither the Group main effects nor the Group x Treatment interactions were significant. However, the Treatment main effects were significant. This indicated that the proportion of first round hits per static and moving target was higher in the field than in the TB. For static targets the proportion of hits was 0.585 (SD = 0.101) in the field and 0.483 (SD = 0.111) in the TB. For moving targets, the average was 0.458 (SD = 0.149) in the field and 0.390 (SD = 0.120) in the TB.

Collectively, these results indicate that TB and field performance were not markedly different. There was no difference in the frequency with which targets were engaged. This suggests that the TB was not any more or less difficult an environment in which to engage targets than a field range. Further, experienced shooters hit as many targets in the TB as in the field for both static and moving targets. The only caveats to this conclusion are that

- although more rounds were fired in the TB than in the field (even with extreme shooter performance removed), TB/field differences were reduced when TB firing followed field firing.

- first round hit rates were lower in the field than the TB, suggesting that firing strategies in the TB and field may have been different.

Target Variable Analysis

Three primary variables were manipulated to define the day defense scenario targets: Range, Exposure Time, and Speed. To study the relationship between TB and field performance in more depth, analyses were performed to include the effects of these variables on performance. Their effect on rate of firing performance measures was also evaluated. The results of these analyses are summarized below. Appendixes H and J (see Volume II) present the full set of results. Mns and SDs for these analyses are provided in Appendixes I and K (see Volume II).

Target Engagements. Tables 5 and 6 present the proportion of target engagements in the TB and field as a function of Range and Exposure Time for static targets and slow (6 fps) and fast moving (12 fps) targets, respectively. Group, Treatment, and the Group x Treatment interaction were not significant for either static or moving target engagements.

For static targets, analysis of variance showed that both the Range and Exposure Time effects were significant. The interaction between these effects was also significant. Inspection of Table 5 shows that

- static target engagements were uniformly high at all combinations of Range and Exposure Time in the TB and field.

TABLE 5
Proportion of Static Targets Engaged in Test Bed and Field (Parametric Experiment)

	Exposure Time (sec)	60 m	120 m	180 m	250 m	300 m
Test Bed	3.25	0.98	0.90	0.87	0.81	0.72
	5.25	0.99	0.98	0.97	0.97	0.93
	7.25	0.97	0.99	0.99	0.97	0.97
Field	3.25	0.97	0.91	0.80	0.83	0.68
	5.25	0.99	0.96	0.98	0.98	0.93
	7.25	0.99	0.94	0.98	0.92	0.95

TABLE 6

Proportion of Moving Targets Engaged in the Test Bed and Field by Target Speed, Exposure Time, and Range (Parametric Experiment)

Test Environment	Target Speed (ft/sec)	Exposure Time (sec)	Target Range		
			60 m	120 m	180 m
Test Bed	6	3.25	0.97	0.97	0.91
		5.25	0.99	1.00	1.00
Field		3.25	1.00	0.91	0.97
		5.25	0.99	0.98	1.00
Test Bed	12	3.25	1.00	0.98	0.96
		5.25	0.99	1.00	0.98
Field		3.25	0.98	0.98	0.97
		5.25	0.97	0.97	1.00

- engagements decreased as range increased, and increased as exposure time increased.

- Engagements decreased more for 3.25-second targets than for 5.25- and 7.25-second targets. (This reflects the significant Range x Exposure Time interaction.)

For moving targets, the results for Exposure Time and the Range x Exposure Time interaction were the same as for the static target analysis. Both were significant at $p < 0.01$. Range, however, was not significant. An inspection of Table 6 indicates that

- moving target engagements were uniform at all combinations of Range, Exposure Time, and Speed.

- engagements tended to increase as Exposure Time increased.

- engagements appeared to decrease with Range for the 3.25-second targets but only marginally or not at all for the 5.25-second targets.

Additionally, the Treatment x Range and the Speed x Exposure Time interactions were significant for moving targets. Tables 7 and 8 present data for these interactions. In Table 7, the proportion of target engagements in the TB is equal for the 60- and 120-meter ranges but drops slightly for the 180-meter range. In the field, engagements are about the same for the 60- and 180-meter ranges but drops slightly for the 120-meter range. This result suggests that moving 120-meter targets in the field may have been slightly more difficult to detect than in the TB, while 180-meter targets in the TB may have been slightly more difficult to detect than in the field.

Table 8 shows that the proportion of moving target engagements was high and about the same for the fast moving targets for the two exposure times investigated in the experiment. However, engagements were slightly fewer for the 3.25-second exposure time for the slow moving targets but increased to the fast moving target levels when exposure time increased to 5.25 seconds. This result shows that the engagability of briefly exposed targets is improved by increased target speed, while the engagability of slow moving targets is improved by increasing exposure time.

Targets Hit. Analysis of variance of the proportion of static targets hit produced nonsignificant Group and Treatment main effects and a nonsignificant Group x Treatment interaction. However, this analysis showed that the Range and Exposure Time main effects and the Range x Time and the Treatment x Range x Time interactions were significant at the $p < 0.01$ level.

Figure 6 presents the Treatment x Range x Exposure Time interaction. It also shows the effect of Range and Exposure Time and the Range x Time interaction. Inspection of this figure indicates that

- static target hits decreased with increases in Range and increased with increases in Exposure Time.

TABLE 7

Proportion of Moving Targets Engaged in the Test Bed
and Field by Target Range
(Parametric Experiment)

Test Environment	Target Range		
	60 m	120 m	180 m
Testbed	0.99	0.99	0.96
Field	0.99	0.95	0.99

TABLE 8

Proportion of Moving Targets Engaged by
Target Speed and Exposure Time
(Parametric Experiment)

Speed (ft/sec)	Exposure Time (sec)	
	3.25	5.25
6	0.95	0.99
12	0.97	0.99

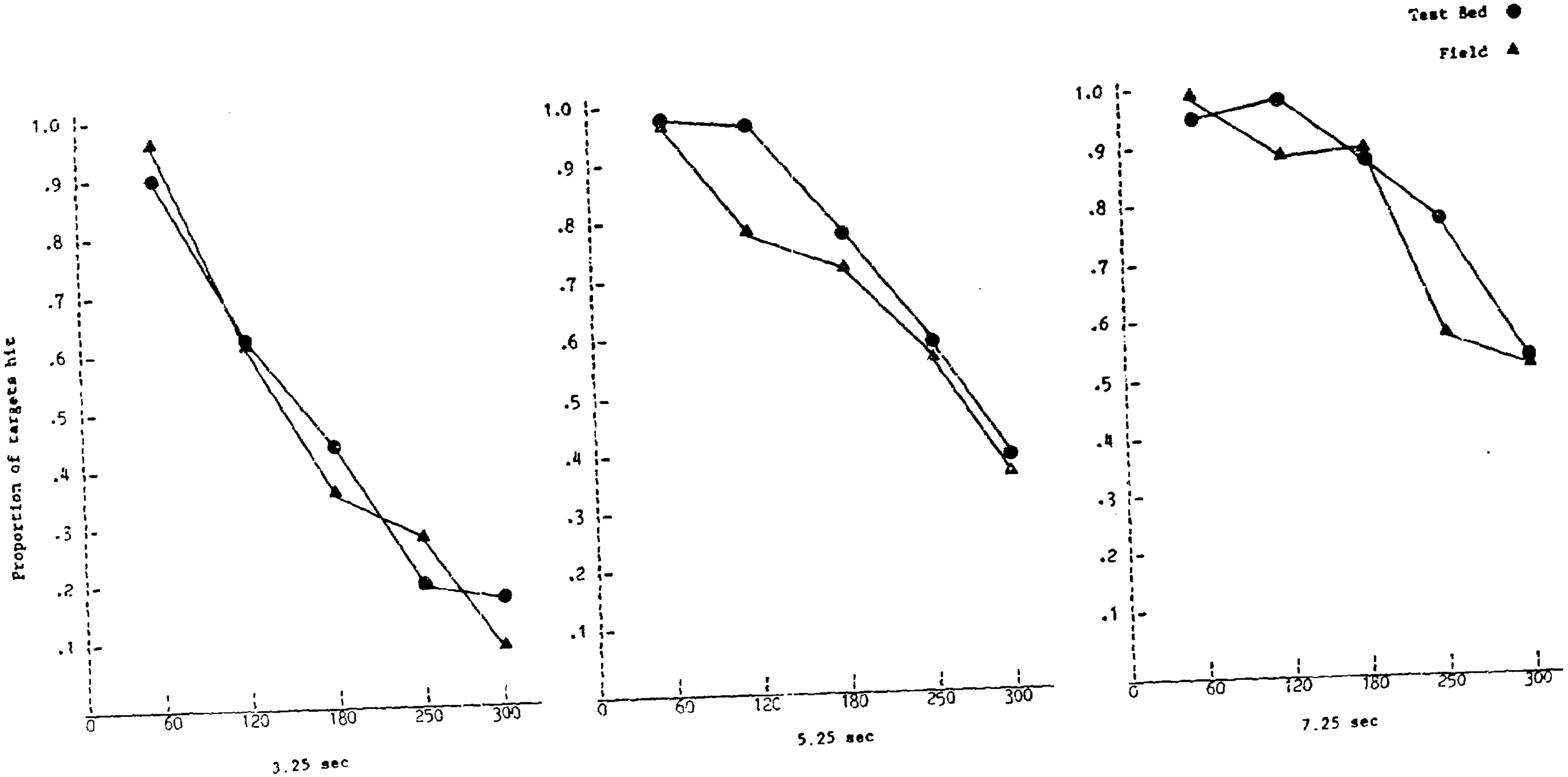


Figure 6. Proportion of static targets hit as a function of range and exposure time.

- static target hits decreased at a faster rate for 3.25-second exposure times than for 5.25- and 7.25-second exposure times.

- Static target hits decreased at about the same rate for 5.25- and 7.25-second exposure times.

Therefore, the differences in the rate at which targets were hit as a function of exposure time was the basis for the significant Treatment x Range x Exposure time interaction.

Analysis of variance of the proportion of hits on moving targets yielded results similar to those for static target hits. The Group and Treatment main effects and the Group x Treatment interaction were each nonsignificant.

The Treatment x Exposure Time interaction was significant for hits on moving targets. As shown in Figure 7, the proportion of target hits increased as exposure time increased from 3.25 to 5.25 seconds. However, this increase was much greater for the TB than for the field. This result suggests that for some of the longer exposure moving targets shooters in the TB may have had an advantage that allowed them to hit more targets. Possible explanations include

- Shooter engagement strategies in the TB may have been different than in the field and led to an advantage in obtaining more moving target hits.

- A difference in the amount of time targets was actually available for engagement may have existed between the TB and the field for the 5.25-second exposures.

This later explanation is unlikely since measurements taken subsequent to the validation experiments indicate TB target exposure times were not greater than field exposure times. (Torre, Maxey, and Christou, In press)

Both the Range and Exposure Time main effects were significant at $p < 0.01$. The Range X Exposure Time interaction was also significant at this level. Figure 8 illustrates this interaction. Inspection of this figure shows that

- Hits on moving targets decreased with increased range.

- Hits on moving targets increased as exposure time increased.

- Moving target hits tended to decrease more rapidly with range for 3.25-second exposure times than for 5.25-second times.

The analysis of variance for hits on moving targets also produced a significant Speed main effect. Figure 9 illustrates this effect on target hits. For both the TB and the field, as target speed increased from 6 to 12 the proportion of hits decreased for both 3.25- and 5.25-second exposure times.

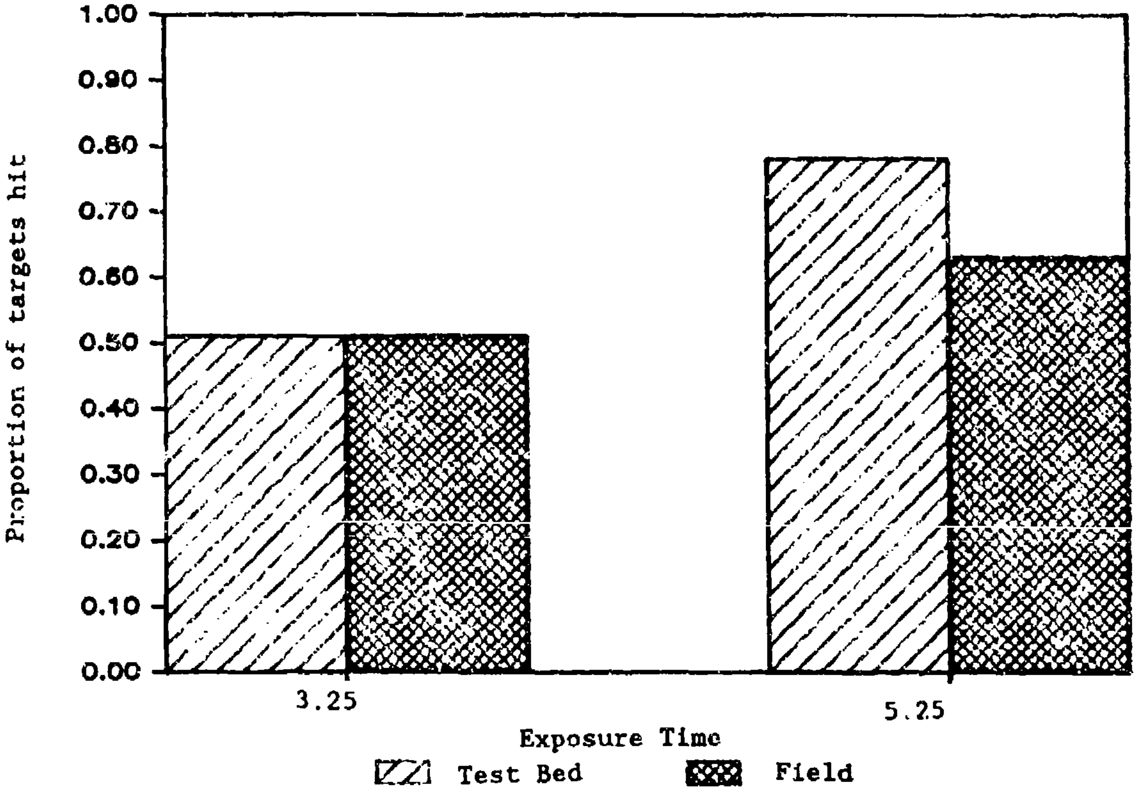


Figure 7. Proportion of moving targets hit as a function of treatment and exposure time.

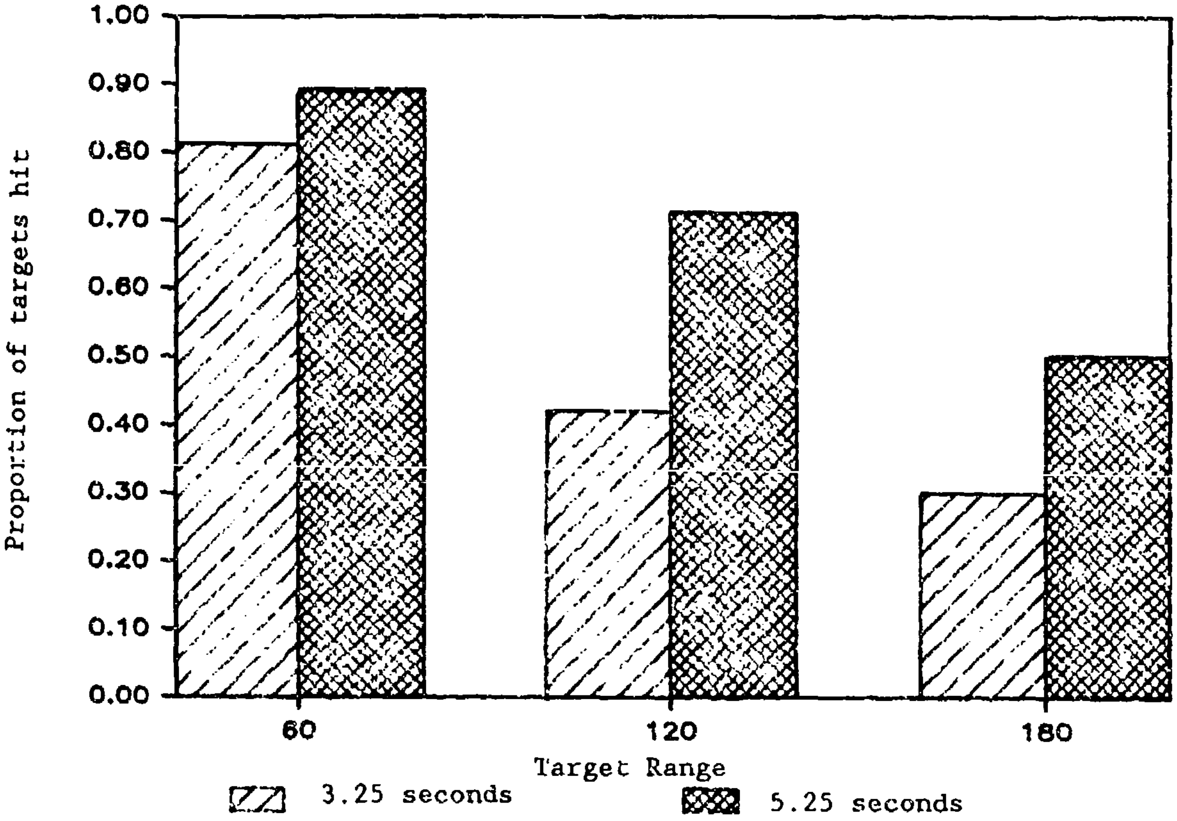


Figure 8. Proportion of moving targets hit as a function of exposure time and target range.

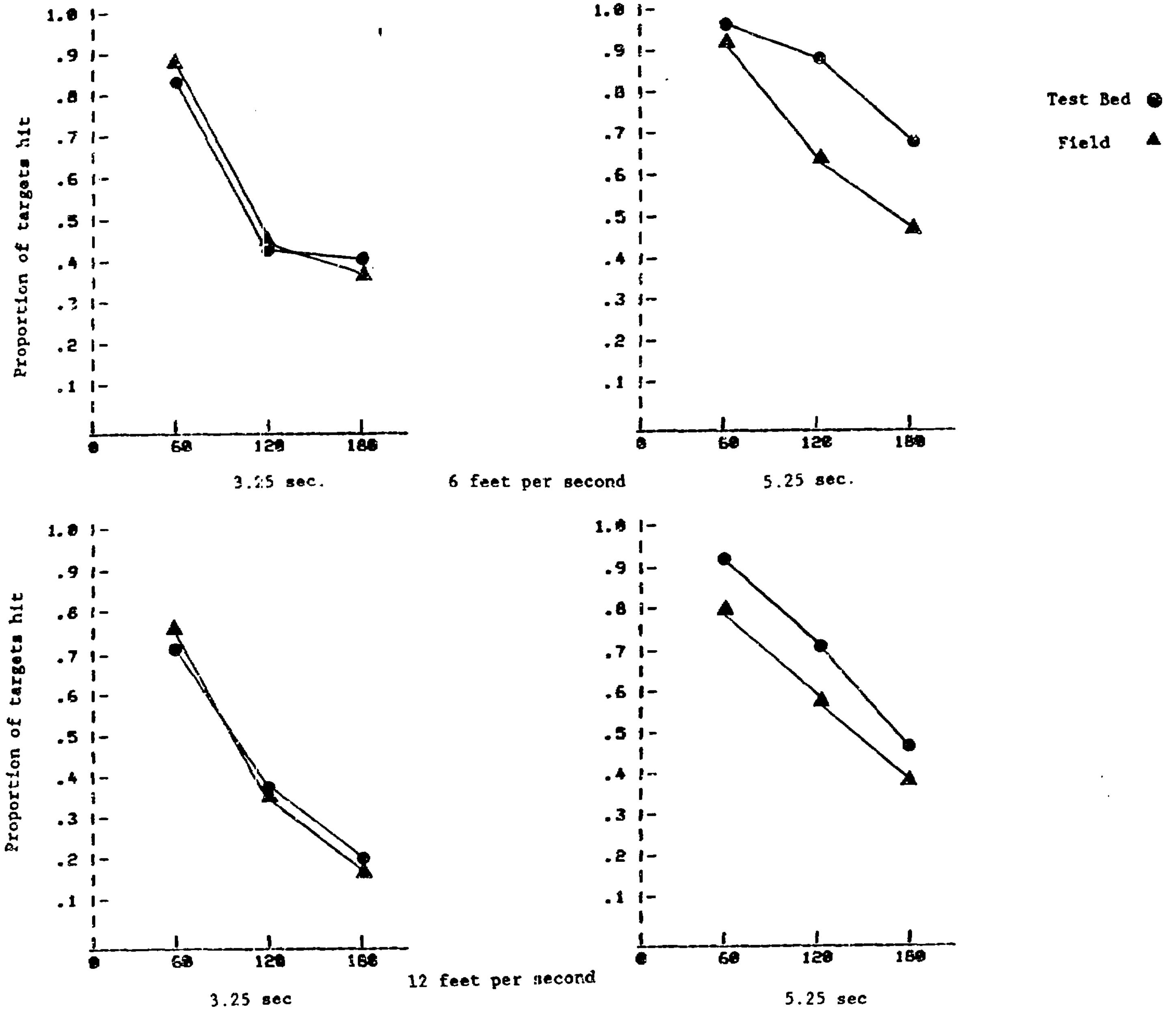


Figure 9. Proportion of moving targets hit as a function of range, exposure time, and speed.

Rounds Fired. Analysis of variance of the number of rounds fired per target for static engagements yielded a number of significant main effects and interactions:

Main Effects

- Treatment
- Range
- Exposure Time

Interactions

- Group x Treatment
- Group x Range
- Treatment x Exposure Time
- Range x Exposure Time
- Treatment x Range x Exposure Time

Figure 10 displays the Treatment x Range interaction, which incorporates the main effects of Treatment and Range. As shown in this figure, the number of rounds fired in the TB was greater than the field for each range. In the field, shooters fired close to one round per target across all ranges with this number increasing slightly with range. However, in the TB, the shooters tended to fire between 1.5 and 2 rounds per target with this number increasing markedly from the 120- to the 300-meter range.

Figure 11 presents the Treatment x Range x Exposure Time interaction. It reflects the main effects of Exposure Time as well as Treatment and Range. In addition, it shows the Treatment x Exposure Time and the Range x Exposure Time interactions. Referring to the figure, more rounds were fired in the TB than the field for each combination of range and exposure time. As exposure time increased, so did the number of rounds fired in either the TB or the field.

For 3.25-second exposure times, the number of rounds fired in the TB tended to decrease with range. In the field they remained about the same at each range. In contrast for the 5.25- and 7.25-second exposure times, in the field and the TB the number of rounds fired tended to increase with range. However, this increase was greater for the TB than the field. This result clearly indicates that different firing strategies were used in the TB and the field. It seems reasonable to suggest that in the TB shooters tried to maximize hits with volume fire. In the field they tended to fire single shots at each target presumably with the idea that they might not be able to fire another shot.

Analysis of variance of the number of rounds fired per target for moving engagements also yielded a variety of significant main effects and interactions:

Main Effects

- Treatment
- Range
- Speed
- Exposure Time

Interactions

- Group x Treatment x Exposure Time
- Group x Range
- Treatment x Speed x Range
- Treatment x Exposure Time
- Exposure Time x Range
- Exposure Time x Speed

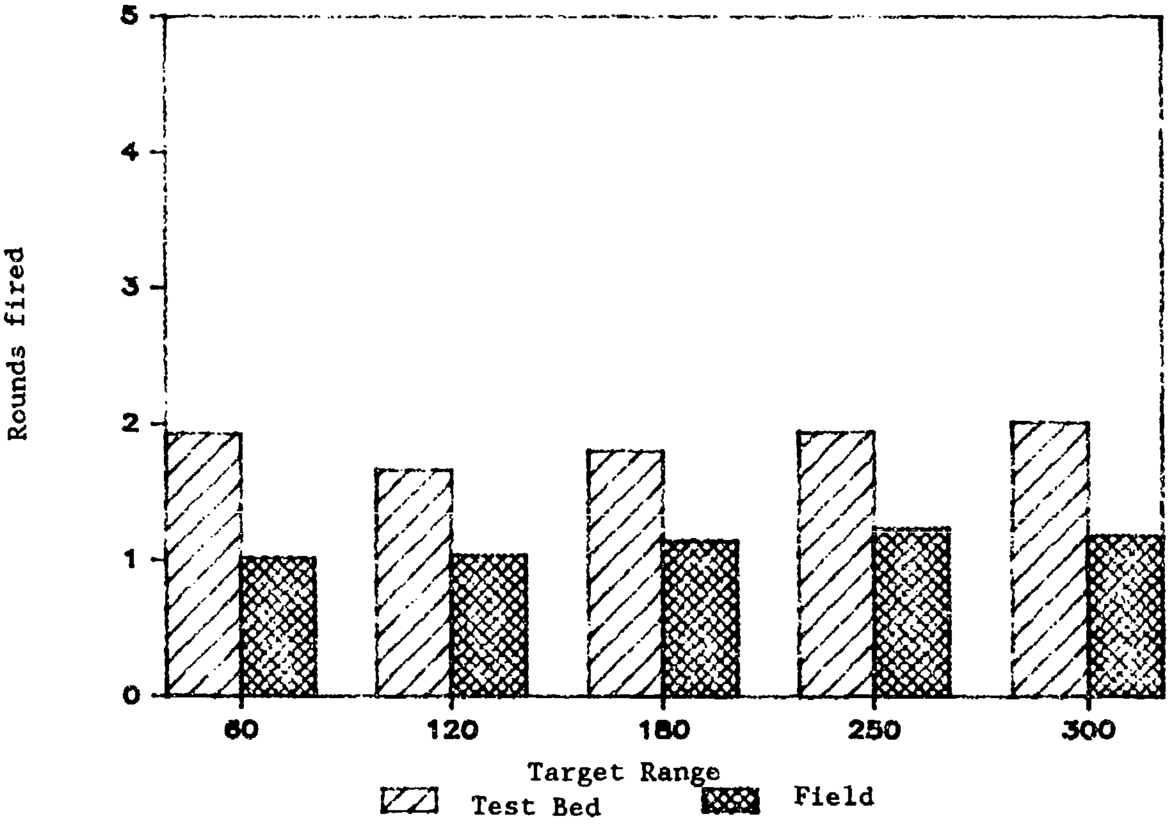


Figure 10. Rounds fired per static target as a function of treatment and target range.

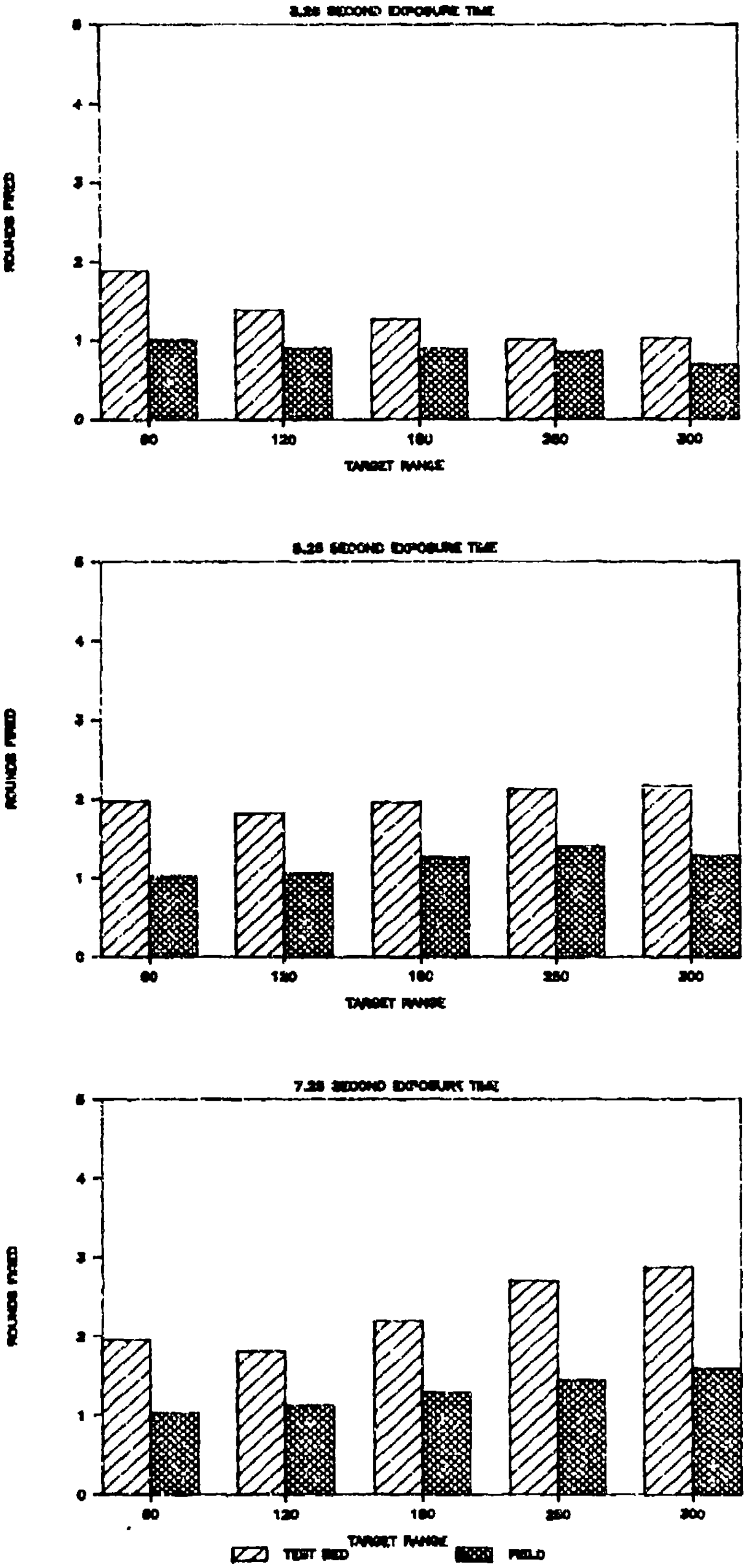


Figure 11. Rounds fired per static target as a function of treatment, target range, and exposure time.

Figure 12 illustrates both the Treatment x Exposure Time and the Group x Treatment x Exposure Time interactions. These figures also illustrate the main effects of Treatment and Exposure Time on number of rounds fired for moving targets. As shown in this figure more rounds were fired by the Alpha and Bravo Groups at moving targets in the TB than the field for both 3.25- and 5.25-second exposure times. Further, more rounds were fired at the longer exposure time than the shorter time. However, as time increased from 3.25- to 5.25-seconds, the number of rounds fired in the TB increased substantially more than in the field, i.e., a 55- versus 43-percent increase (taken across the Alpha and Bravo Groups).

Additionally, for both groups the pattern of the Group x Treatment x Exposure Time interaction was the same. However, the increase in rounds fired at the 5.25-second exposure time for TB engagements was much larger for the Alpha group (61 percent) than the Bravo group (48 percent). Clearly this difference is responsible for the significant Group x Treatment x Exposure Time interaction. This indicates that for moving target engagements, the two groups also had different firing strategies, e.g., Alpha group shooters tended to fire more rounds when they had the opportunity than the Bravo shooters.

Figure 13 presents the Group x Range interaction. It shows the effect of Group on the relationship between the Range main effect and rounds fired at moving targets. For the Alpha group, rounds fired was high for 60-meter targets, then lower for 120-meter targets, and then high again for 180-meter targets. For the Bravo group rounds fired was low for 60-meter targets and then increased with range. The basis for this result is not apparent from the data.

Figure 14 presents the Treatment x Speed x Range interaction. It shows the effect of Treatment on the relationship between Speed and Range. For both the TB and the field, more rounds were fired at the faster targets than the slower targets across the 60-, 120-, and 180-meter ranges.

Finally, Figures 15 and 16 present the Exposure Time x Range and the Exposure Time x Speed interactions, respectively. Figure 15 indicates that across all moving target ranges more rounds were fired at 5.25-second targets than 3.25-second targets. However, as range decreased in either the TB or the field, the number of rounds fired decreased for the 3.25-second exposure times but increased for the 5.25-second times. This result probably reflects the operation of two factors:

- More distant targets usually require more time for a good shot.
- The longer a target is exposed, the more shots that can be fired at it.

Thus with short duration targets, the trend would be to reduce the number of shots with range and cause the number of rounds fired to converge toward one shot per target, which is what Figure 15 shows for the 3.25-second exposures. For longer duration targets, however, there would be ample opportunity to fire extra shots at each range when misses occurred so it would be expected that the number of shots fired would increase with range, which is what Figure 12 shows for the 5.25-second targets.

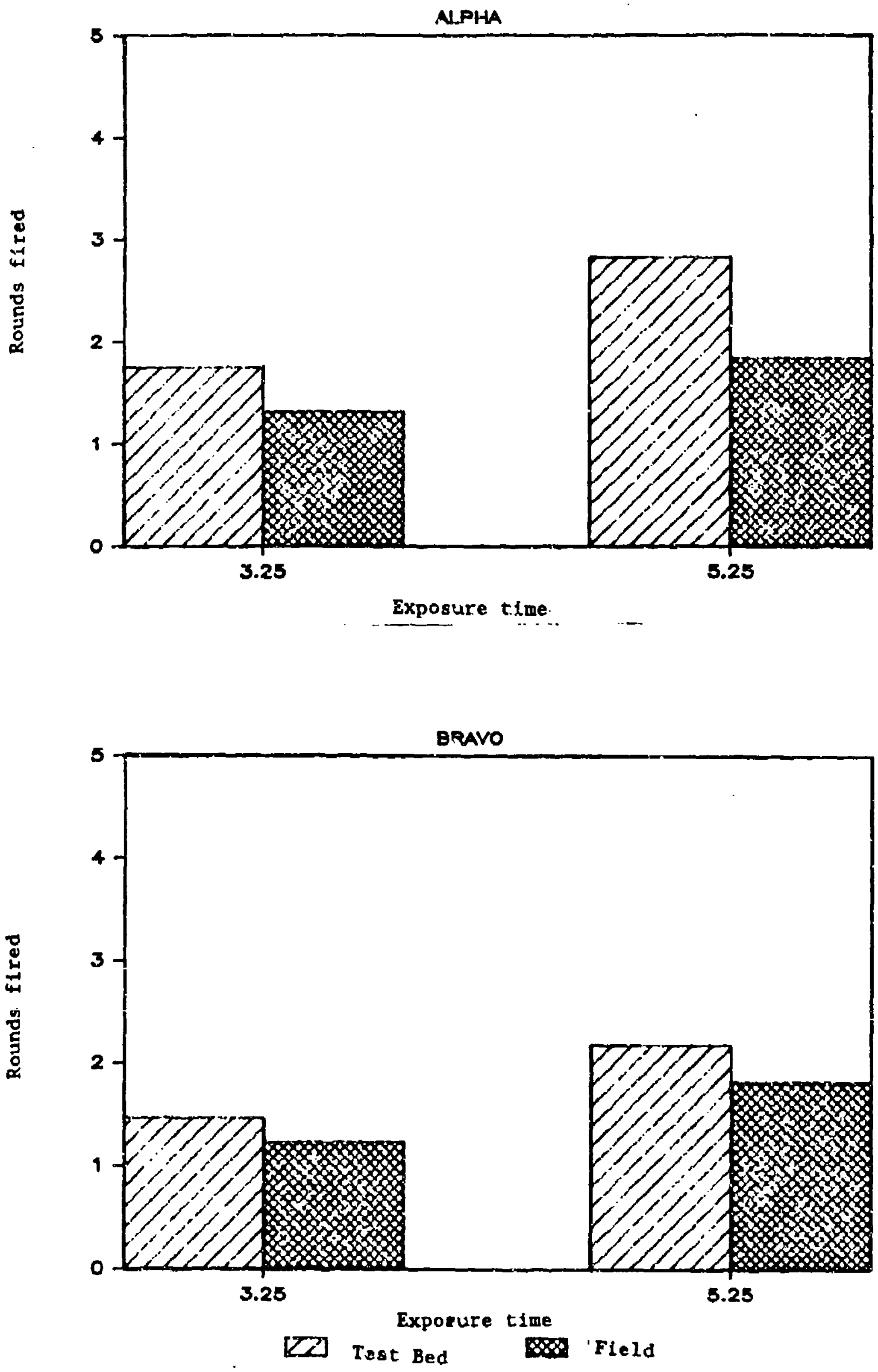


Figure 12. Rounds fired per moving target as a function of group, treatment, and exposure time.

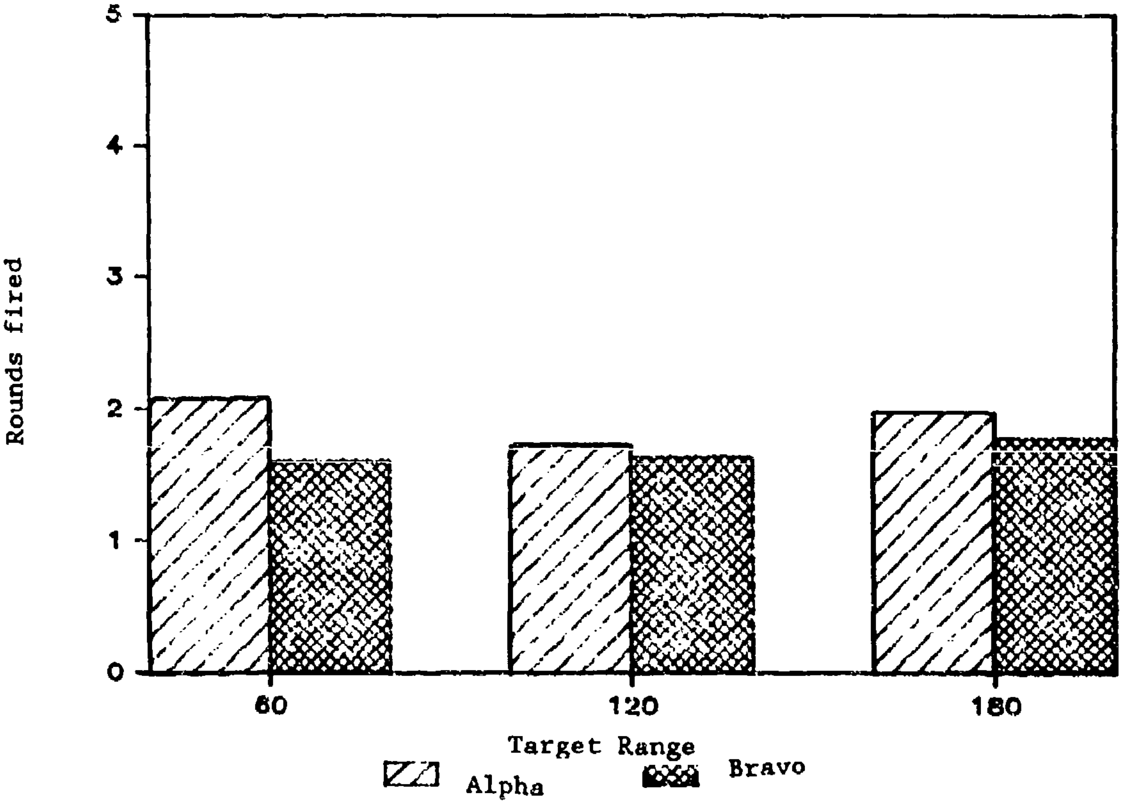


Figure 13. Rounds fired per moving target as a function of group and target range.

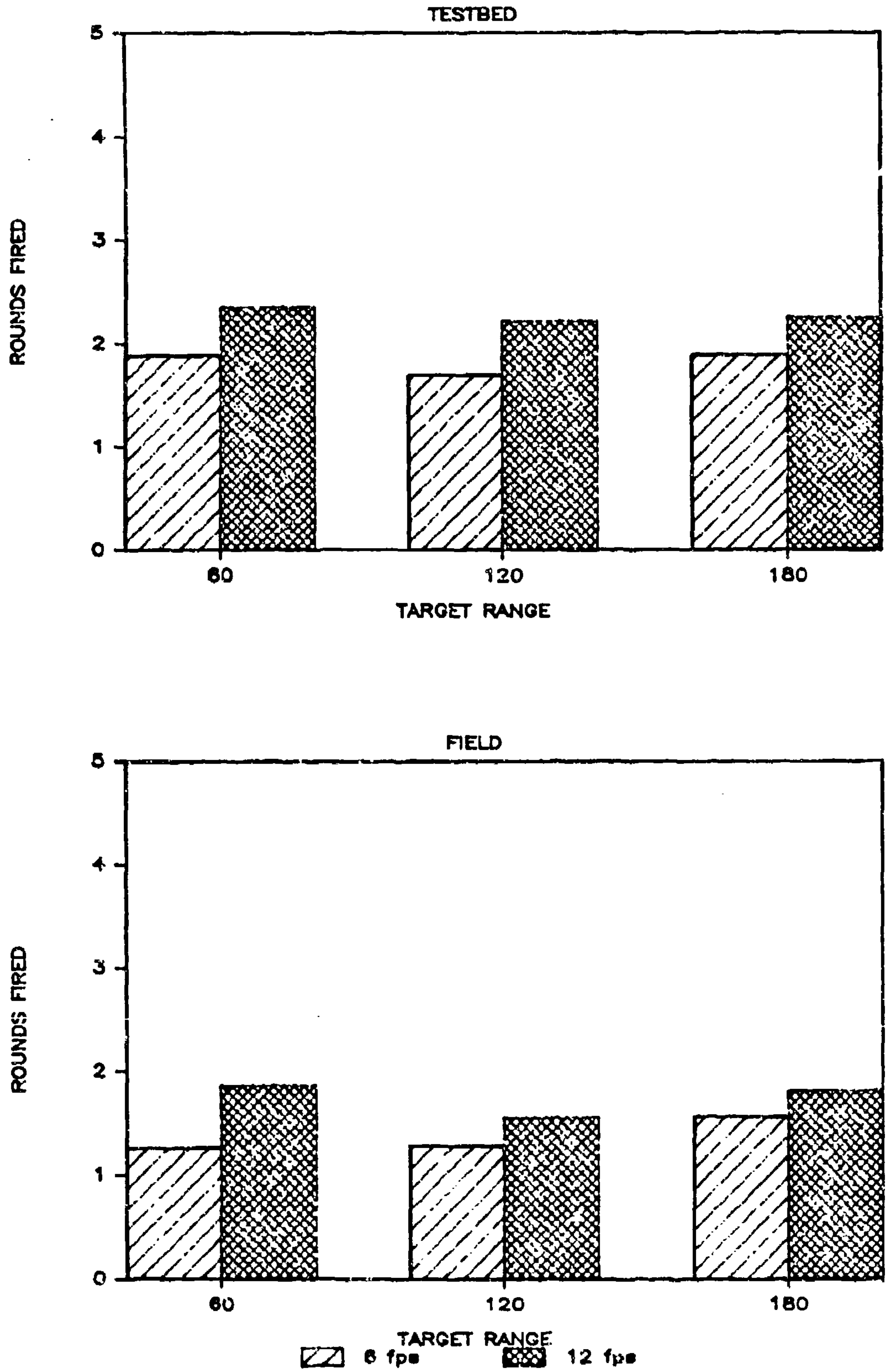


Figure 14. Rounds fired per moving target as a function of treatment, target range, and exposure time.

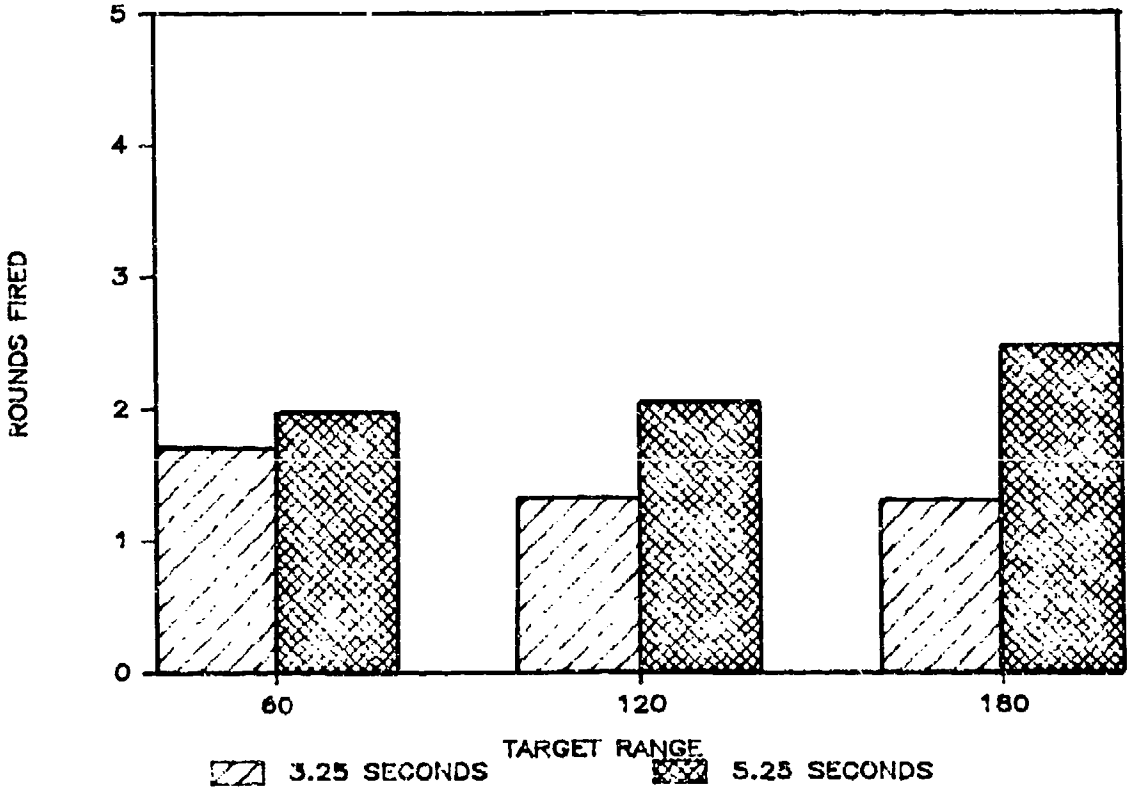


Figure 15. Rounds fired per moving target as a function of exposure time and target range.

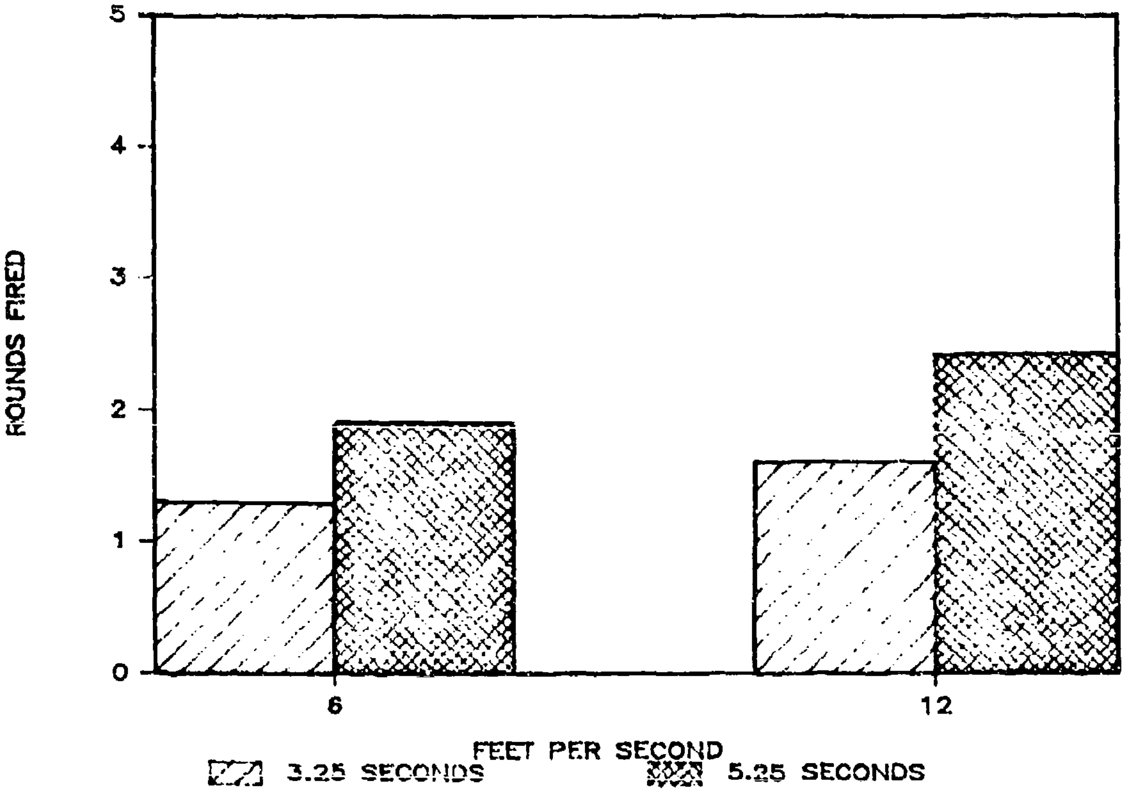


Figure 16. Rounds fired per moving target as a function of exposure time and target speed.

Figure 16 indicates that the number of rounds fired was greater for the longer, 5.25-second targets than for the shorter, 3.25- second targets. Further, as target speed increased in both the TB and the field, the number of rounds fired increased. However, this increase was greater for 5.25-second target exposures than for 3.25-second exposures. This result probably reflects the operation of two factors:

- As target speed increases, firing rate increases to compensate for difficulties in maintaining target track.
- The longer a target is exposed, the more shots that can be fired at it.

Thus, for short duration, slow targets the firing rate would be low and there would be less time to shoot and fewer rounds fired. For short duration, fast targets there would still be less time to shoot but the rate would be higher so there would be more rounds fired. For both short and long duration targets for longer exposure times, there would be more opportunity to shoot to compensate for misses with the higher firing rate for fast moving targets leading to proportionally more total rounds fired than for the slower targets. The end result would be the interaction portrayed in Figure 16.

First Round Hits. Figure 17 presents the proportion of first round hits in the TB and field as a function of Range and Exposure Time for static targets. Figure 18 shows the proportion of first round hits for moving targets as a function of range and speed. As mentioned earlier, the Group and the Group Treatment interaction were not significant for either static or moving first round hits. However, the Treatment effect was found to be significant at $p < 0.01$ for both static and moving targets.

For static targets, the analysis of variance also showed that both the Range and Exposure Time effects were significant at $p < 0.01$. Additionally, there was a significant interaction of these effects with the Treatment main effect. An inspection of Figure 17 indicates that

- first round hits in the TB and field occurred at about the same level for 3.25-second exposure times at each target range and decreased at about the same rate as range increased.
- first round hits in the TB occurred less often that in the field for 5.25-second exposure times at each target range but decreased at about the same rate in both environments as range increased.
- first round hits in the TB generally occurred less often and decreased at a faster rate with range in the TB than the field for 7.25-second exposure times.

Therefore, the basis for the Treatment x Range x Exposure Time interaction was the differences in the way first round hits decreased with increases in both Range and Exposure Time with the differences being larger for targets at the 180- to 300-meter ranges and exposure times of 5.25- and 7.25-seconds.

Analysis of variance of the proportion of hits on moving targets yielded results similar to those for static targets. As noted before, the Group main

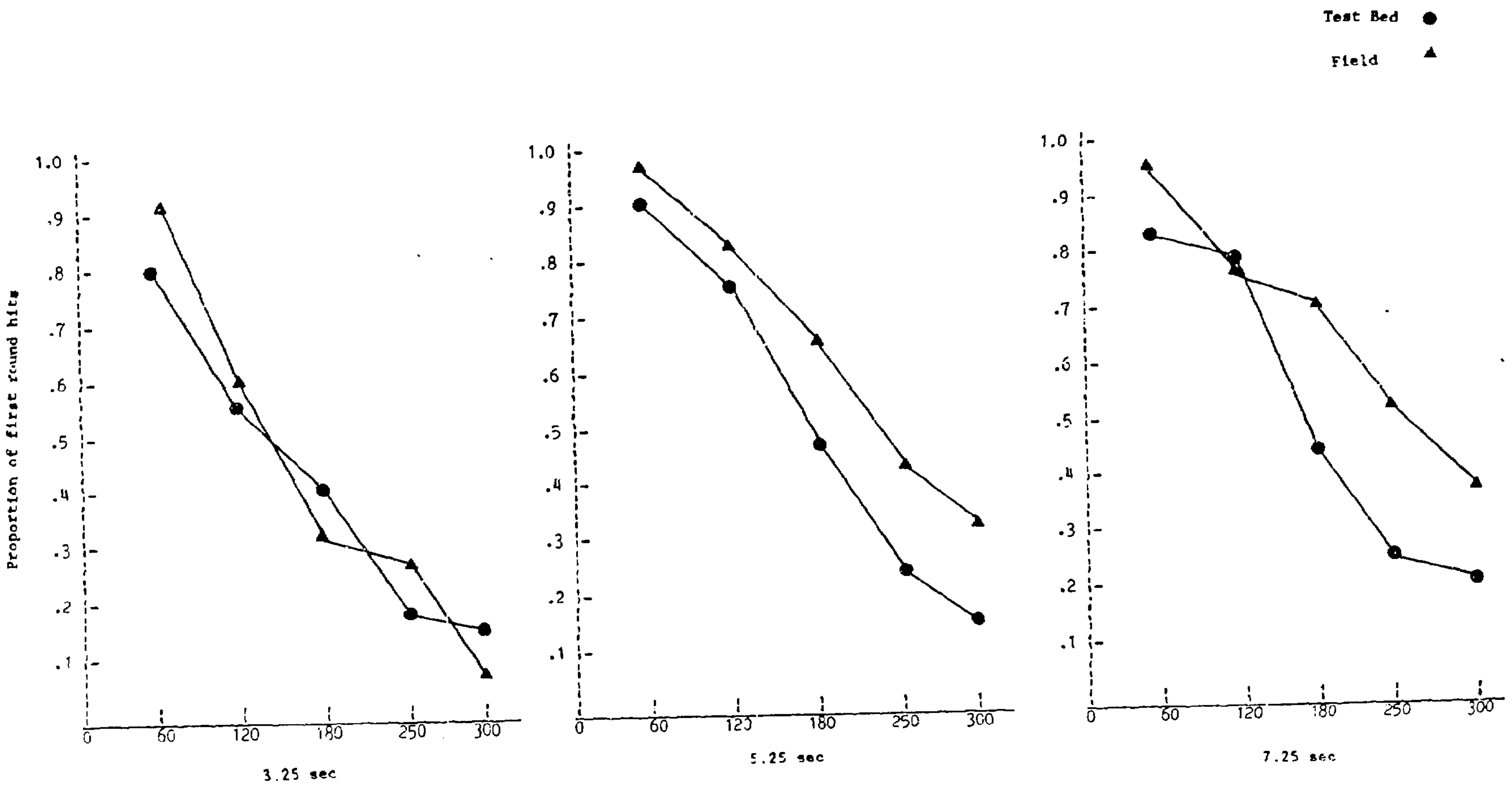


Figure 17. Proportion of first round hits on static targets as a function of range and exposure time.

effect and the Group x Treatment interaction were not significant. However, the Treatment effect was significant. Range and Speed were also significant. So was the Range x Speed interaction. However, Exposure Time was not significant. Neither were any of the other interactions.

Figure 18 shows the Range x Speed interaction for first round hits on moving targets. It also illustrates main effects of Treatment, Range, and Speed. An inspection of this figure indicates that

- First round hits decreased with increases in target range.
- First round hits decreased as target speed increased.
- The significant Range x Speed interaction was due to a major difference in the way first round hits decreased with range for slow and fast moving targets, but the basis for this difference was not apparent from the data.

Rate of Firing Measures. The influence of Range, Exposure Time, and Speed on three rate of firing measures of marksmanship performance was assessed:

- Time to fire first round
- Time to first hit
- Number of rounds to first hit

The results of these analyses are provided in Appendix J for static and moving targets. Mns and SDs for each combination of treatment, range, exposure time, and speed are reported in Appendix K, Volume II. Figures showing the effect of these variables are provided in Appendix L, Volume II. Generally these analyses showed the following:

- The Alpha and Bravo group shooters tended to fire their first round at targets sooner in the TB than the field.
- The Alpha and Bravo group shooters tended to obtain their first hit sooner in the TB than the field.
- The Alpha and Bravo group shooters tended to require more rounds to obtain their first hit in the TB than the field.

These results again reinforce the finding that in the TB the shooters apparently employed a different firing strategy than in the field.

TRAINING EXPERIMENT

Zeroing Task

Performance on this task was measured in terms of the number of rounds the ROTC, Alpha, and Bravo shooters required to zero the rifle. Table 9 presents the Mns and SDs for the three groups for the TB and the field. For the ROTC group, two values are provided for this measure for the TB: the number of rounds the ROTC shooters took to achieve their first zero and the number of rounds they required to achieve the last zero they shot.

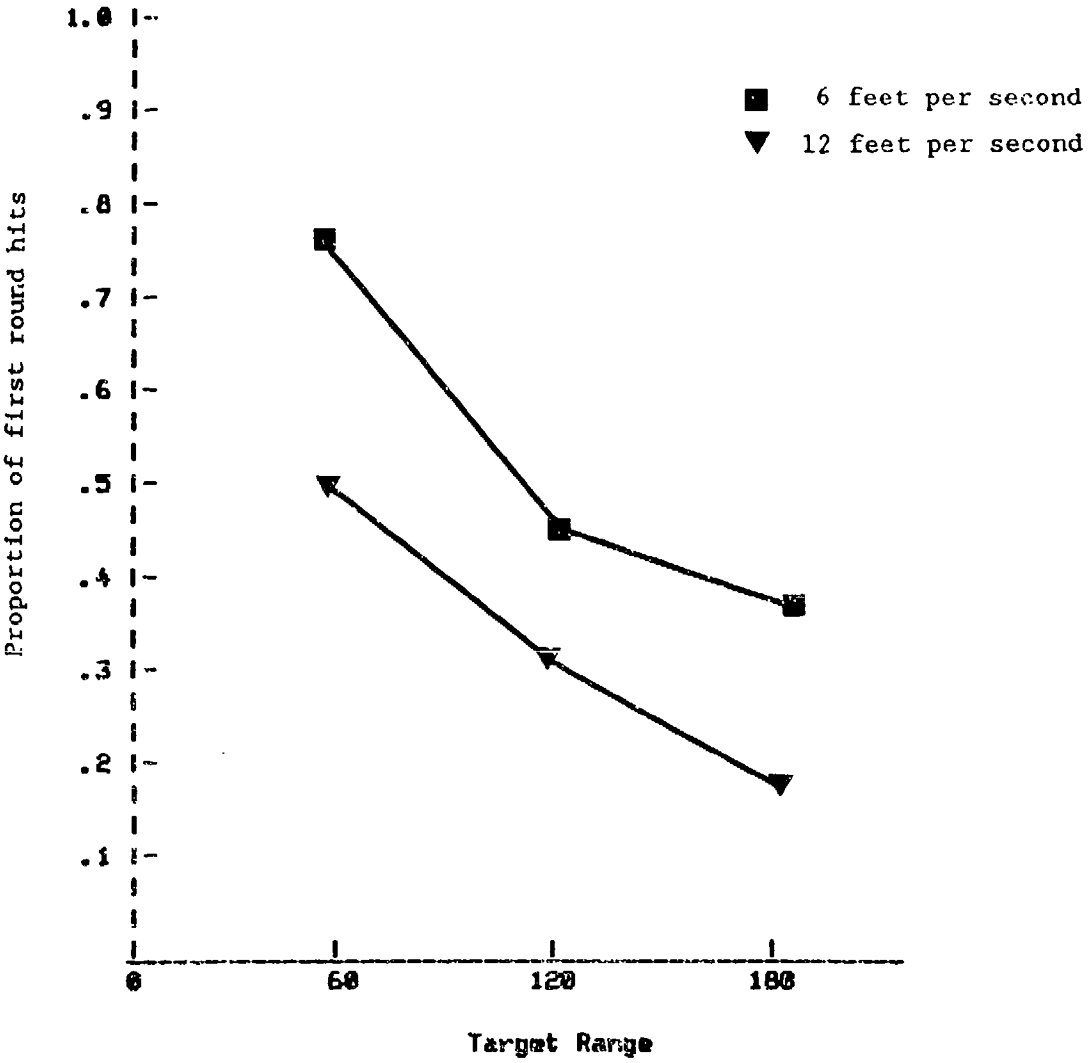


Figure 18. Proportion of first round hits on moving targets as a function of range and speed.

TABLE 9

Measures of Marksmanship Performance in the Test Bed and Field for the Alpha, Bravo, and ROTC Groups

		Test Bed				Field		
Measure		Alpha	Bravo	ROTC		Alpha	Bravo	ROTC
				First	Last			
Zero Task								
	N	15	14	7	9	15	14	9
Rounds to Zero	Mn	32.4	24.0	52.0	17.0	30.6	28.5	23.3
	SD	12.0	21.1	34.7	12.6	20.7	19.4	7.0
Self-Paced Task								
	N	15	14	9		15	14	8
Diameter (Covering Circle)	Mn	1.86	2.02	2.59		2.13	2.13	1.94
of Group (mils)	SD	0.54	0.48	0.81		0.67	0.49	0.60
	N	15	14	9		15	14	9
SD of Aiming Accuracy (mils)	Mn	0.52	0.53	0.68		0.55	0.54	0.51
	SD	0.14	0.10	0.20		0.17	0.13	0.11
	N	15	14	8		15	14	9
Number of Hits on Target Silouette	Mn	9.07	8.29	7.67		8.20	8.36	8.78
	SD	1.28	1.54	2.12		1.21	1.29	0.97

Table 10 summarizes the results of repeated-measurements analysis of variance for the number of rounds to zero. Two sets of results are provided, one that includes the data for the ROTC group's rounds to first zero and one that includes the data for their last zero. Appendix H contains the full set of results for both analyses.

Neither of the main effects was significant for the analysis involving the ROTC group's rounds to first zero in the TB. However, their interaction was significant. For the analysis involving this group's rounds to last zero in the TB, neither main effect nor the interaction was significant.

These results show that in the early phases of skill acquisition, the ROTC shooters were not as proficient as the experienced shooters, e.g., ROTC Mn = 52.0 rounds compared to Alpha Mn = 32.4 rounds, and Bravo Mn = 24.0 rounds. This was not unexpected. However, by the completion of their training, the ROTC shooters took no more rounds to zero their rifle in the TB (ROTC Mn = 17.0 rounds) than in the field (ROTC Mn = 23.3 rounds) or than the Alpha or Bravo groups shooters took.

Self-Paced Task

Performance on this task was measured in terms of the diameter (covering circle) of the 10-round group, the SD of aiming accuracy, and the number of hits on the zero target silhouette. Table 9 also presents the Mns and SDs for these measures for the ROTC, Alpha, and Bravo groups for the TB and field.

Table 10 presents a summary of the results of repeated-measurements analysis of variance for the self-paced task measures. The full set of analysis results are presented in Appendix H, Volume II. None of the main effects or interactions in any analysis were significant at the 0.01-level. These results indicate that in the TB or the field, the ROTC group shooters did not perform any differently on this task than either the Alpha or Bravo shooters.

Day Defense Scenario Task

Performance measures on this task were proportion of targets engaged, proportion of targets hit one or more times, number of rounds fired per target, and the proportion of first round hits on targets across the 2-day defense scenarios in the field. Table 11 presents the Mns and SDs for these measures for the ROTC, Alpha, and Bravo groups for the TB and the field static amd moving targets. Additionally, this table summarizes the results of a one-way analysis of variance that tested the difference among the groups.

In only two cases were significant differences ($p < 0.01$) among group means identified: the number of rounds fired per static target engaged and the proportion of first round hits on static targets. In both cases, the advantage was with the Army shooters. For number of rounds fired, the average performance of the Alpha and Bravo shooters was 1.08 (SD = 0.09) and 1.15 (SD = 0.12) rounds, respectively. In contrast, the average performance of the ROTC shooters was 1.63 (SD = 0.30) rounds. For proportion of first round hits, the average performance of the Alpha and Bravo group shooters was 0.629 (SD = 0.094) hits, respectively. The average performance of the ROTC shooters, however, was 0.453 (SD = 0.130) hits.

TABLE 10

Summary of Significance Tests for Zero and Self-Paced Marksmanship Performance Measures in the Test Bed and Field for the Alpha, Bravo, and ROTC Groups

	Group (G) Alpha vs Bravo vs ROTC			Treatment(T) Test Bed (T) vs Field (F)			Interaction G x T		
Measure	F	df	P	F	df	P	F	df	P
Zero Task									
Rounds to Zero (ROTC Group's First Zero)	1.45	2,35	0.25	4.18	1,35	0.05	4.96	2,35	0.01 **
Rounds to Zero (ROTC Group's Last Zero)	2.02	2,35	0.15	0.75	1,35	0.39	0.53	2,35	0.59
Self-Paced Task									
Diameter (Covering Circle) of Group (mils)	1.01	2,35	0.37	0.55	1,35	0.46	4.51	2,35	0.02
SD of Aiming Accuracy (mils)	0.96	2,35	0.39	2.02	1,35	0.16	3.76	2,35	0.03
Number of Hits on Target Silhouette	0.60	2,35	0.55	0.10	1,35	0.76	2.76	2,35	0.08

** Significant at $p < 0.01$.

TABLE 11

Measures of Marksmanship Performance in the Field by Group and Summary Significance Tests of Group Differences

Measure		Alpha (N=15)	Bravo (N=14)	ROTC (N=9)	F	df	P
Proportion of Targets Engaged							
	N	15	14	9			
Static	Mn	0.912	0.929	0.941	1.51	2,35	0.23
	SD	0.039	0.044	0.038			
Moving	N	15	14	9			
	Mn	0.982	0.966	0.961	1.32	2,35	0.28
	SD	0.022	0.044	0.034			
Proportion of Targets Hit							
	N	15	14	9			
Static	Mn	0.686	0.610	0.623	2.30	2,35	0.11
	SD	0.081	0.089	0.139			
	N	15	14	9			
Moving	Mn	0.578	0.554	0.590	0.15	2,35	0.86
	SD	0.151	0.168	0.182			
Number of Rounds Fired Per Target							
	N	15	14	9			
Static	Mn	1.08	1.15	1.63	32.27	2,35	0.00 *
	SD	0.09	0.12	0.30			
	N	15	14	9			
Moving	Mn	1.60	1.53	1.75	1.82	2,35	0.18
	SD	0.22	0.18	0.43			
Proportion of First Round Hits							
	N	15	14	9			
Static	Mn	0.629	0.539	0.453	8.69	2,35	0.00 *
	SD	0.094	0.089	0.130			
	N	15	14	9			
Moving	Mn	0.453	0.463	0.458	0.02	2,35	0.98
	SD	0.132	0.171	0.145			

* Significant at $p < 0.01$

Collectively, these results indicate the live fire field performance of the TB trained ROTC shooters was very much like that of the two groups of U.S. Army infantrymen. In particular on the fundamental tasks of zeroing and self-paced slow fire the ROTC shooters did not differ from the infantrmen's TB or live fire performance. For the live fire day defense scenario the ROTC shooters did not perform any differently than the infantrymen for the primary performance measure of targets hit. Additionally, the ROTC shooters engaged field targets as often as the infantrymen did. The ROTC shooters' performance did differ, however, from the infantrymen's performance in two ways in the field:

- They fired more rounds at static targets.
- They had lower first round hit rates on static targets.

These results are very similar to the Parametric Experiment results, which showed that the infantrymen fired more rounds and had lower first round hits in the TB than the field.

TARGET VARIABLE ANALYSES

As discussed in the Parametric Experiment, Range, Exposure Time, and Speed were manipulated to define the day defense scenario targets. To study the similarities and differences between the field marksmanship performance of the ROTC and infantrymen shooters, the scenario task data analyses were expanded to include the effects of these variables on field performance. In addition, their effect on rate of firing performance measures was evaluated through repeated-measurements analysis of variance. The results of these analyses are discussed below. The full set of results are present in Appendixes H and J. Mns and SDs for the analyses are presented in Appendixes I and K.

Static Target Analyses. Table 12 summarizes the analysis of variance results for the day defense scenario performance measures for static targets. Analysis of the proportion of targets engaged and targets hit yielded nonsignificant Group main effects and nonsignificant interactions with the Group variable. The Range and Exposure Time main effects and the Range x Exposure Time interactions for the two performance measures, however, were significant. Referring to Table 13 and Figure 19, the following conclusions can be drawn about static target engagements and target hits:

- The performance of the ROTC shooters did not differ significantly from the performance of the U.S. Army infantrymen.
- Engagements and target hits decreased with increased Range and increased Exposure Time.
- Engagements and target hits decreased more rapidly at the 3.25-exposure time than the 5.25- and 7.25-second times.

Analysis of the number of rounds fired and proportion of first round hits yielded significant Group main effects. Also, the Range and Exposure Time main effects and the Range x Exposure Time and Group x Exposure Times interactions for these measures were significant. Finally, for just the number of rounds

TABLE 12

F Values for Significant Main Effects And Interactions For Training Experiment Static Target Analyses

Main Effect/ Interaction	DF	Proportion of Targets Engaged	Proportion of Targets Hit	Number of Rounds Fired Per Target	Proportion of First Round Hits
Group (G)	2,35	-	-	32.27	8.69
Range (R)	4,140	13.51	194.74	38.04	238.79
Exposure Time (T)	2,70	40.50	288.27	208.46	50.79
R x T	8,280	9.54	16.49	39.48	4.16
G x R	8,14	2.88 [1]	-	11.00	-
G x T	8,280	-	-	13.39	12.37
G x R x T	16,280	-	-	3.26	-

[9] This interaction became nonsignificant when the field data were transformed using the transform 2(ARCSIN (SQRT X)).

TABLE 13

Proportion of Static Targets Engaged in the Field for the Alpha, Bravo, and ROTC Groups by Target Exposure Time and Range (Training Experiment)

Group	Exposure Time (sec)	Target Range				
		60 m	120 m	180 m	250 m	300 m
Alpha	3.25	0.98	0.91	0.80	0.80	0.62
	5.25	0.99	0.97	0.99	0.96	0.89
	7.25	1.00	0.92	0.98	0.93	0.94
Bravo	3.25	0.96	0.91	0.80	0.87	0.74
	5.25	0.99	0.95	0.98	1.00	0.96
	7.25	0.98	0.96	0.98	0.91	0.95
ROTC	3.25	0.98	0.89	0.93	0.93	0.80
	5.25	0.91	0.94	0.96	0.96	1.00
	7.25	0.94	1.00	0.94	0.96	0.96

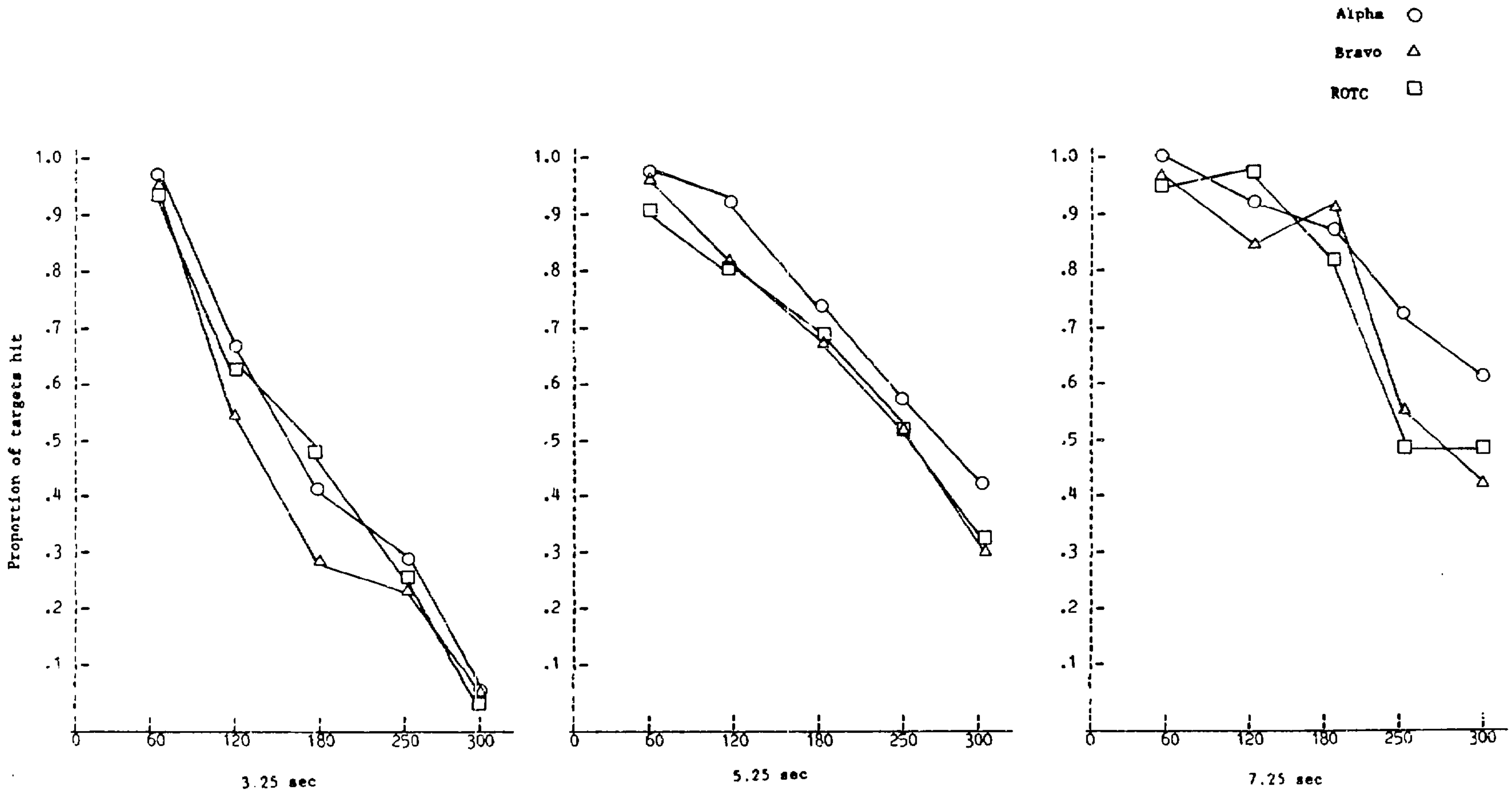


Figure 19. Proportion of static targets hit as a function of range and exposure time.

fired measure, the Group x Range and the Group x Range x Exposure Time interactions were significant.

Referring to Figures 20 and 21, the following conclusions can be drawn about the number of rounds fired and proportion of first round hit measures:

- At the 3.25-second exposure time, the performance of the ROTC group shooters did not differ significantly from the U.S. Army infantrymen.
- At the 5.25- and 7.25-second exposure times, the performance of the ROTC group shooters was less efficient than that of the U.S. Army infantrymen, i.e., they fired progressively larger numbers of rounds and the proportion of first round hits was considerably lower as range increased.

Moving Target Analysis. Table 14 summarizes the analysis of variance results for the day defense scenario performance measures for moving targets. Analysis of the proportion of targets engaged yielded no significant main effects and only one significant interaction, Group x Range x Exposure Time.

Figure 22 presents this interaction. It indicates that as Exposure Time increased for 3.25 to 5.25 seconds, the U.S. Army infantrymen increased the rate at which they engaged targets. In contrast, for the ROTC shooters, this happened only for the 60-meter range targets. Moving target engagements at 120 meters were at a maximum level and increased Exposure Time made no difference here for the ROTC shooters. Finally, for the 180-meter moving targets, increased Exposure Time yielded a decrease in engagements. The basis for these results was not apparent from the data collected during the study.

Analysis of the proportion of targets hit yielded a nonsignificant Group main effect but significant Range, Exposure Time, and Speed main effects. None of the interactions was significant. Figure 23 illustrates these results:

- The ROTC shooters did not differ signficantly for the U.S. Army infantrymen in terms of performance profiles for any combination of range, exposure time, or speed.
- Performance decreased with increases in Range and Speed and improved with increases in Exposure Time.

Analysis of number of rounds fired and proportion of first round hits yielded nonsignificant Group main effects but significant Range and Speed main effects and significant Range x Speed interactions. Additionally, for the number of rounds measure, there was a significant Exposure Time main effect and a significant Range x Exposure Time interaction. Figures 24 through 26 illustrate these results.

Referring to Figures 24 and 25, there were only marginal differences in the number of rounds fired at moving targets as a function of Range, Speed, and Exposure Time; this result reflecting the nonsignificant Group main effect. Comparing slow to fast moving targets it appears that independent of Exposure Time the number of rounds fired at slow moving targets was either constant or increased with range. However, the trend for fast moving targets was to fire more rounds at the 60- and 180-meter targets and fewer at the 120-meter targets. The basis for this finding is not apparent from the study data.

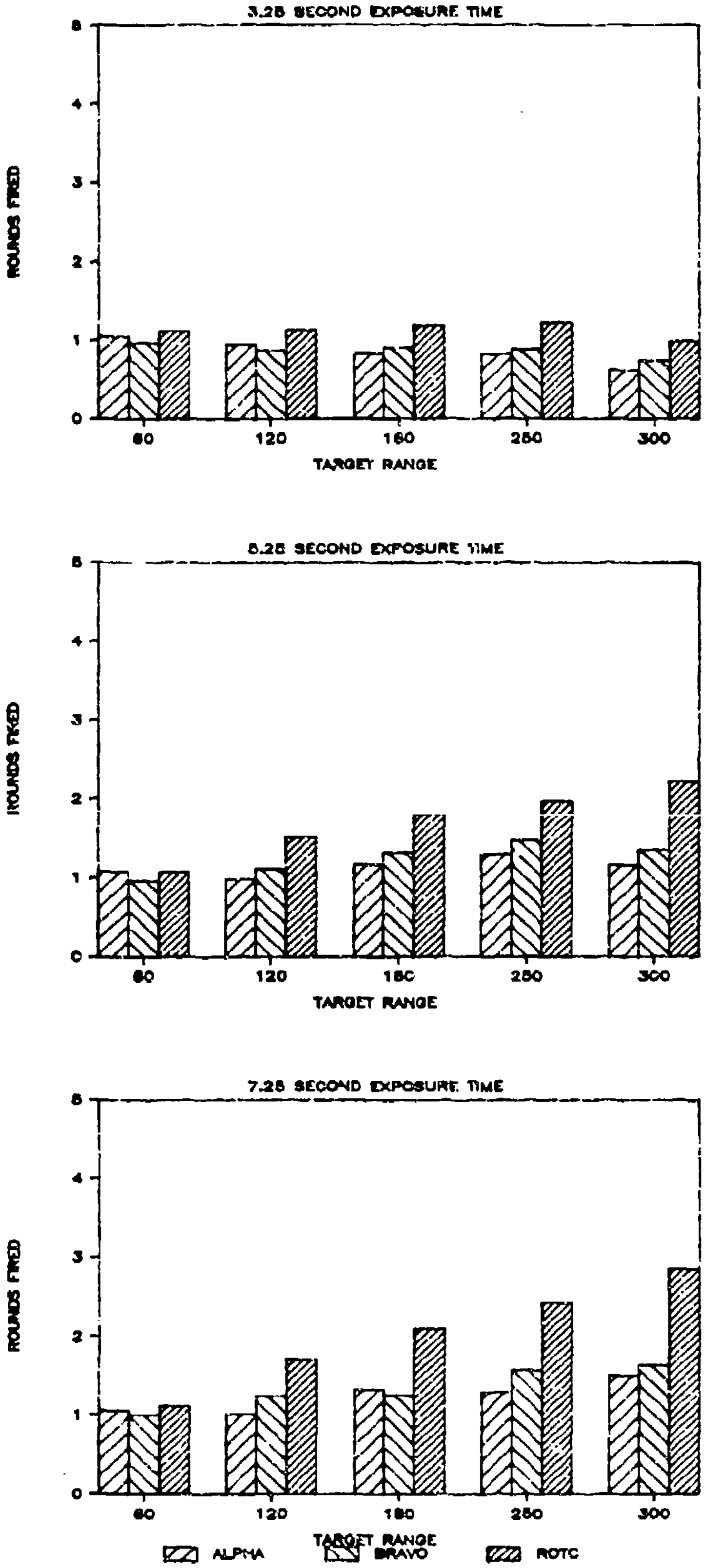


Figure 20. Rounds fired per static target as a function of group, target range, and exposure time.

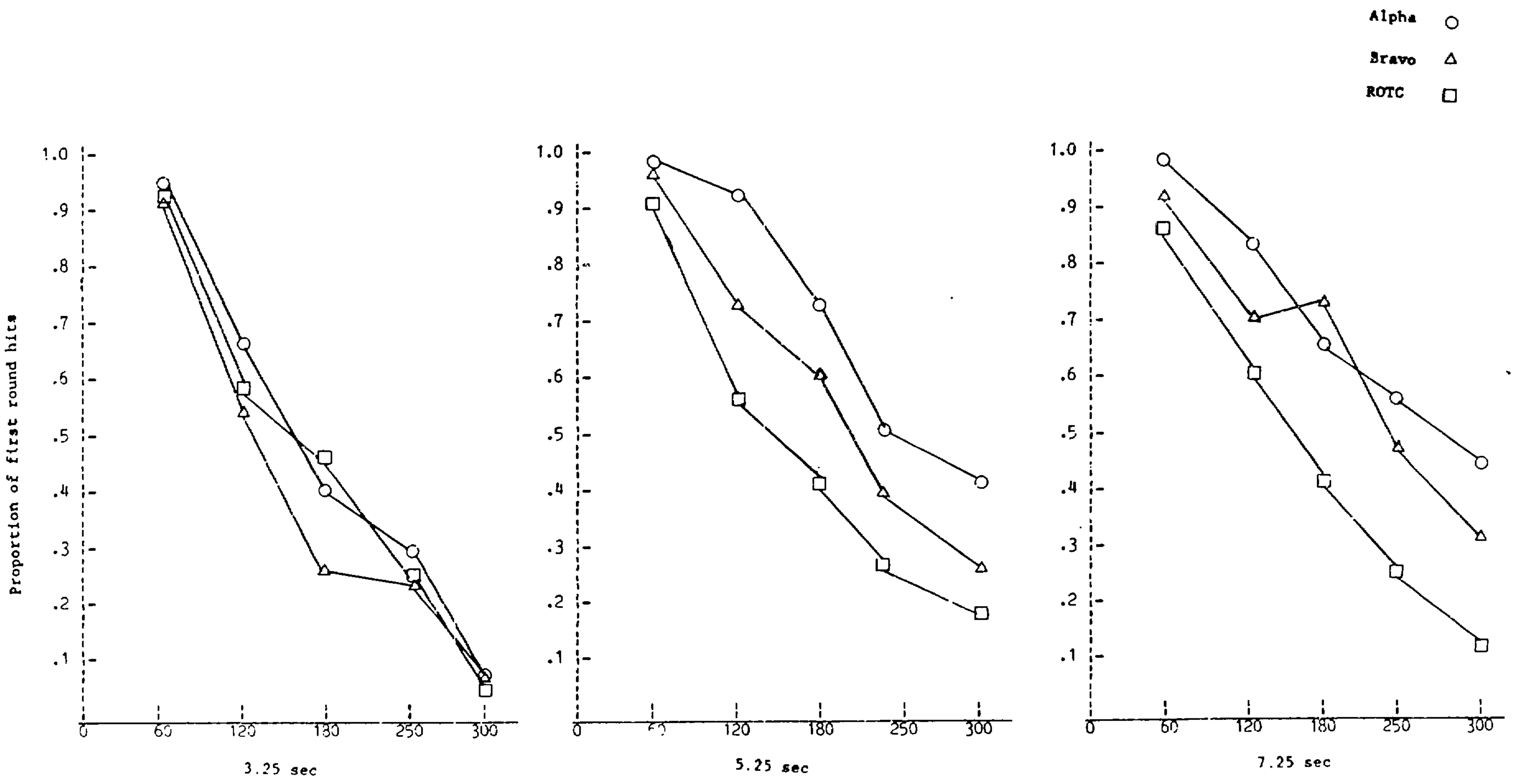


Figure 21. Proportion of first round hits on static targets as a function of range and exposure time.

TABLE 14

F Values for Significant Main Effects And Interactions For Training Experiment Moving Target Analyses

Main Effect/ Interaction	DF	Proportion of Targets Engaged	Proportion of Targets Hit	Number of Rounds Fired Per Target	Proportion of First Round Hits
Group (G)	2,35	-	-	-	-
Range (R)	2,70	-	140.67	7.60	77.06
Exposure Time (T) 233.79 -	1,35	-	54.29		
Speed (S)	1,35	-	22.77	75.55	30.22
R x T	2,70	-	-	36.44	-
R x S	2,70	-	-	11.15	12.46
T x S	1,35	-	-	-	-
R x T x S	2,70	-	-	-	-
G x R	4,70	-	-	-	-
G x T	2,35	-	-	-	-
G x S	2,35	-	-	-	-
G x R x T	4,70	4.52	-	-	-
G x R x S	4,70	-	-	-	-
G x T x S	2,35	-	-	-	-
G x R x T x S	4,70	-	-	-	-

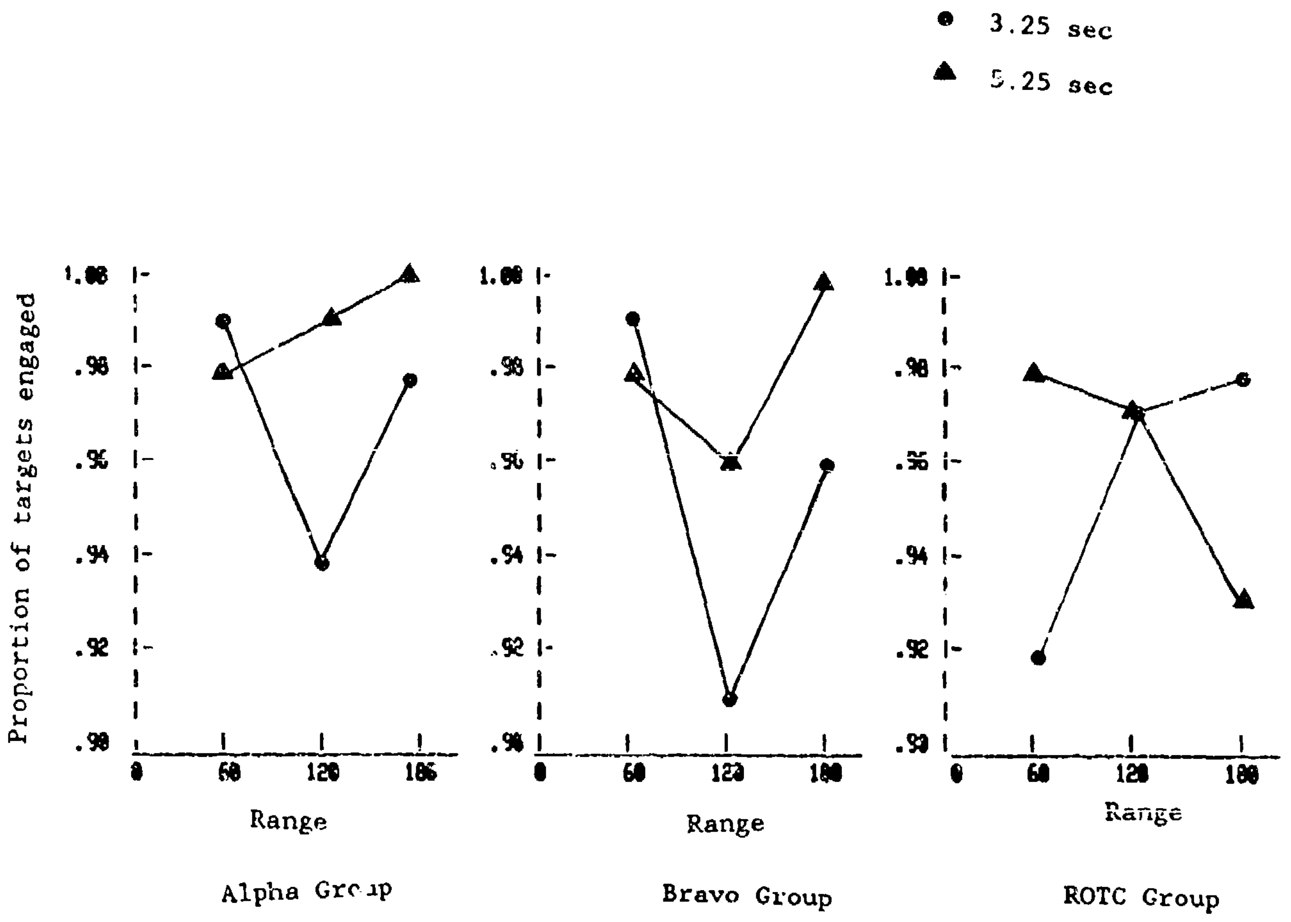


Figure 22. Proportion of moving targets engaged as a function of group, target range, and target exposure time.

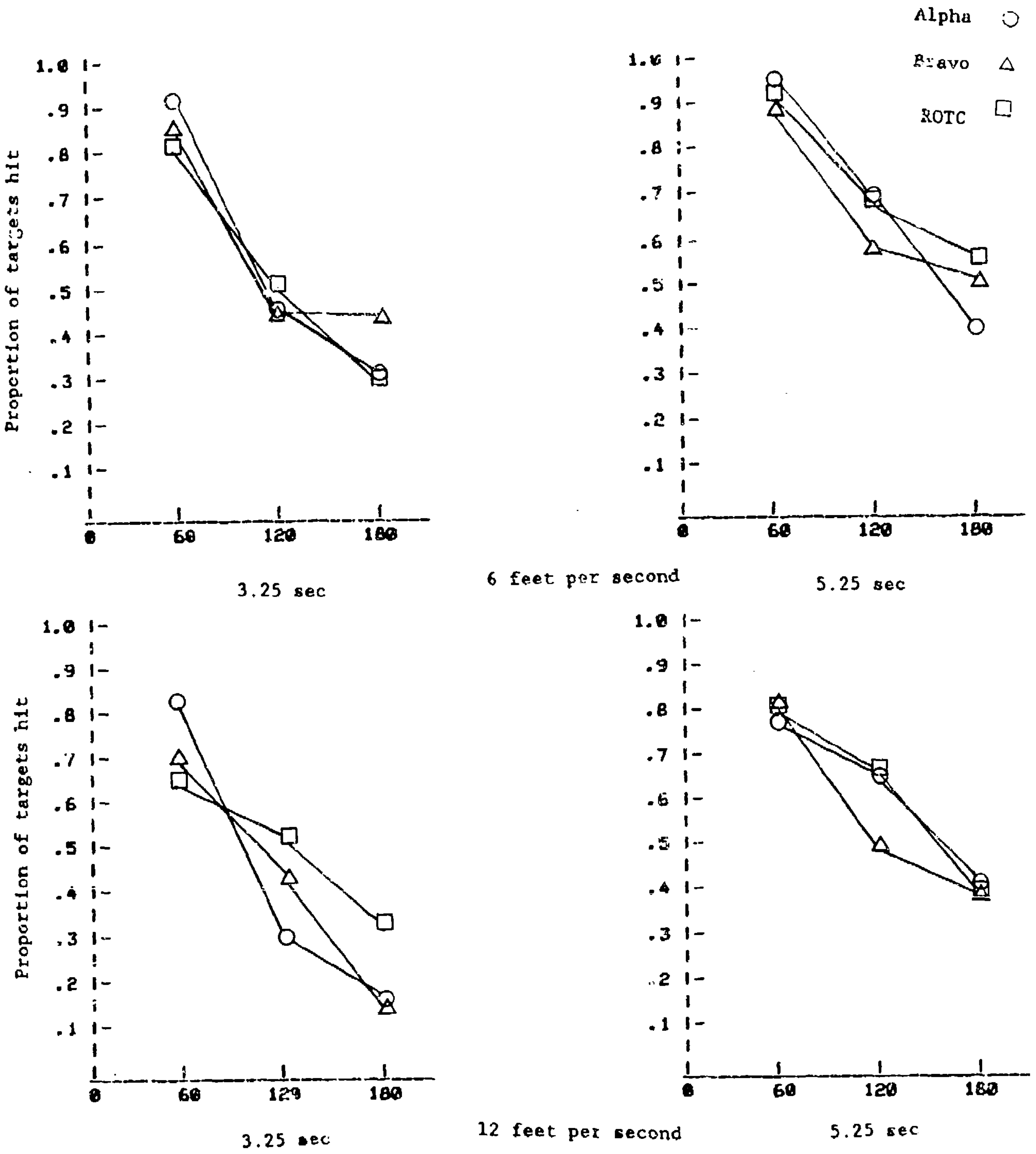


Figure 23. Proportion of moving targets hit as a function of range, exposure time, and speed.

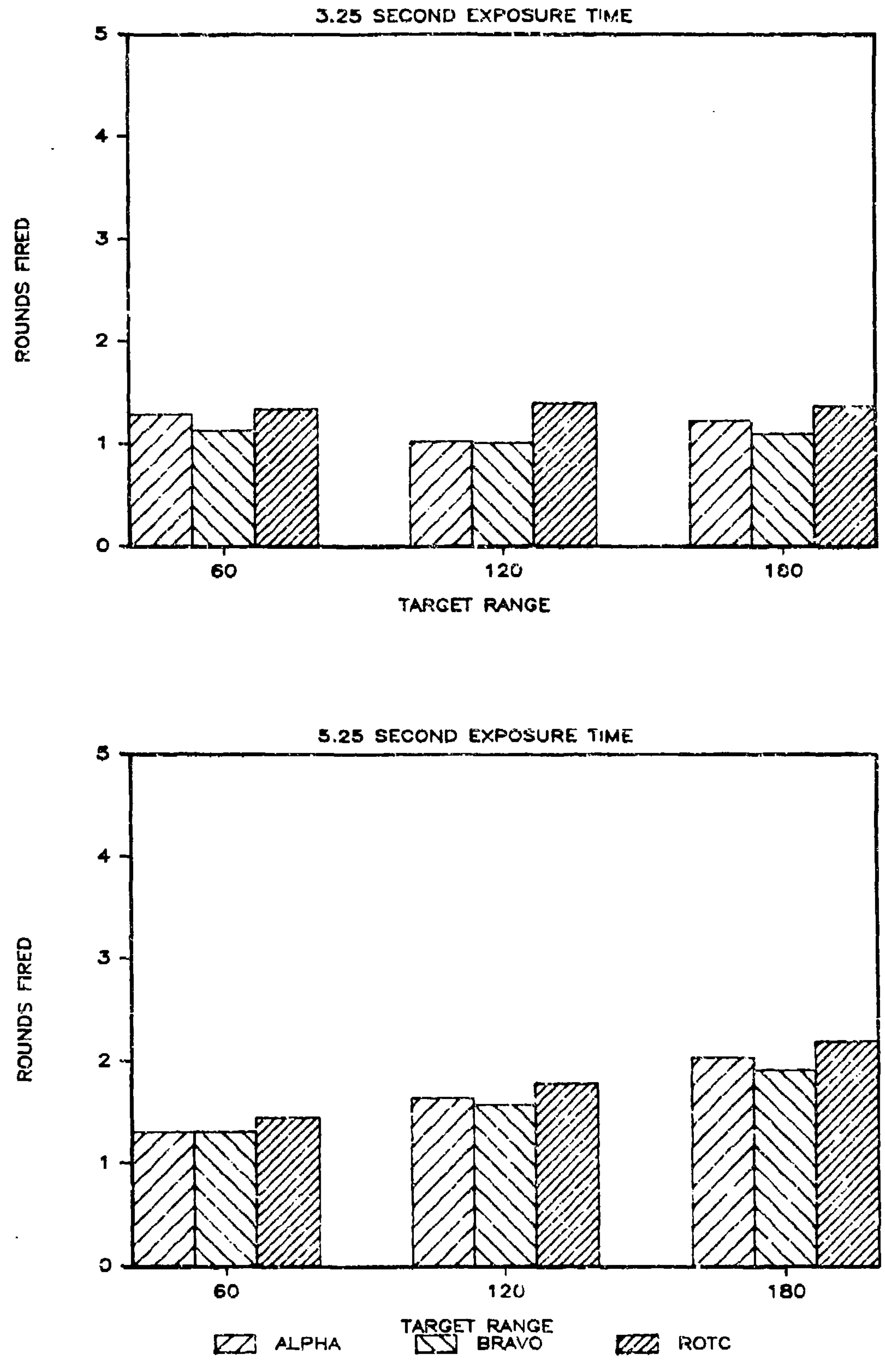


Figure 24. Rounds fired per slow moving target as a function of group, target range, and exposure time.

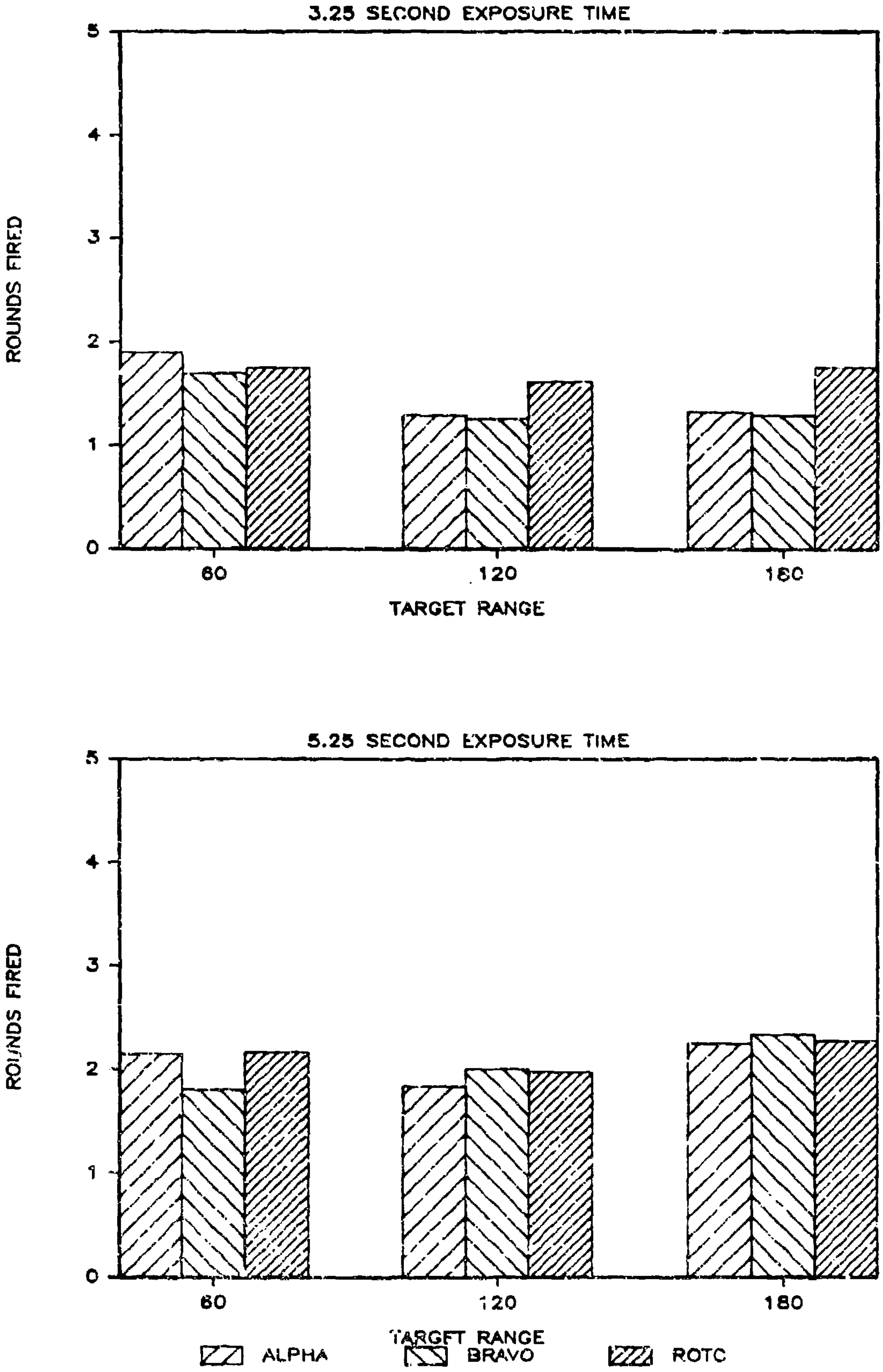


Figure 25. Rounds fired per fast moving target as a function of group, target range, and exposure time.

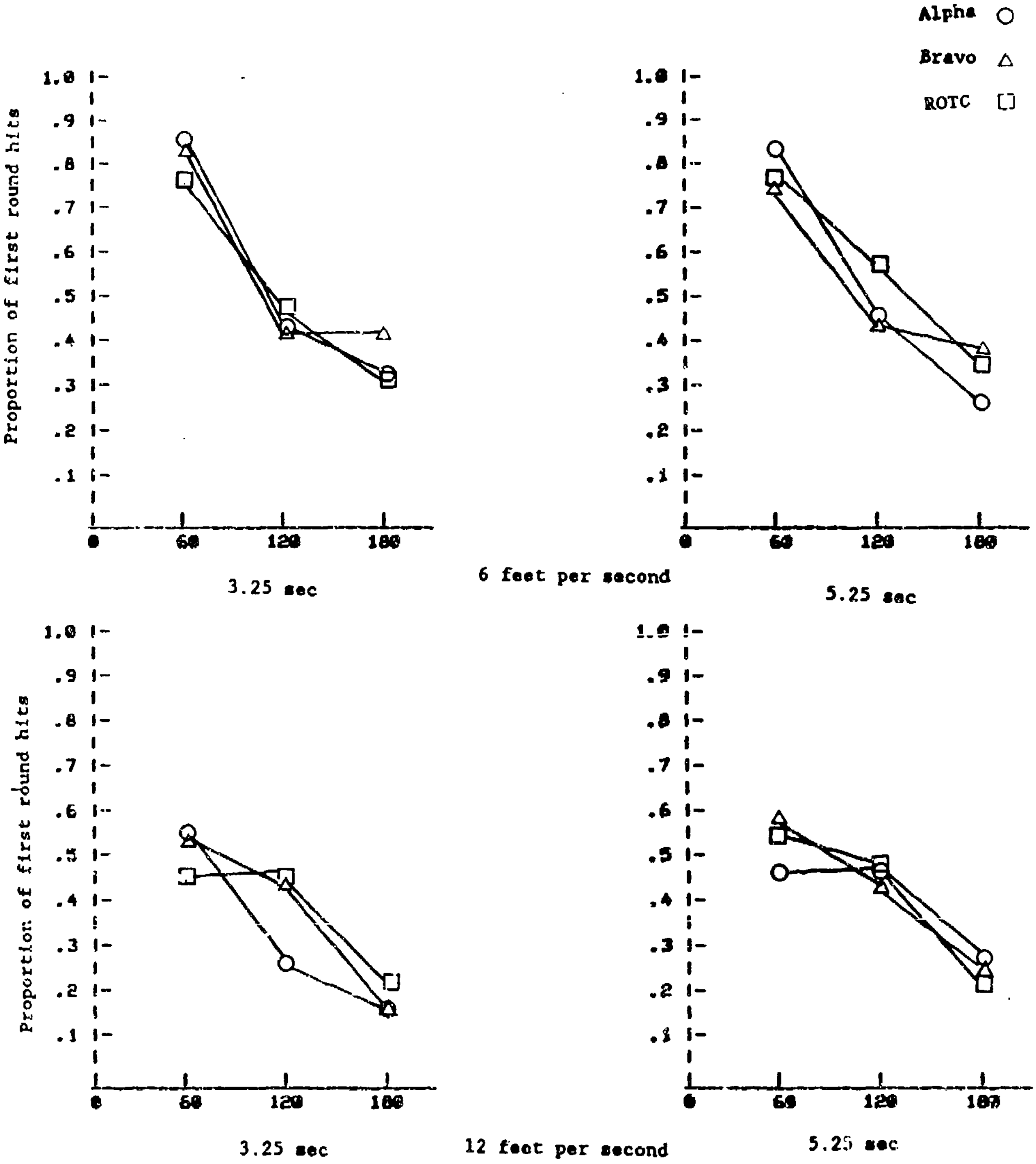


Figure 26. Proportion of first round hits on moving targets as a function of range, exposure time, and speed.

Additionally, it appears that the shooters tended to fire more rounds with increased Exposure Time, especially at the longer range moving targets. Hence, the significant Range x Exposure Time interaction.

Figure 26 illustrates the nonsignificant Group main effect. It shows the effect of Range and Speed on first round hits:

- Shooter performance decreased with increased range and increased speed.
- Performance was better for the 6 fps speed than the 12 fps speed.
- With increases in Range, performance dropped off faster as speed increased from 6 to 12 fps.

Rate of Firing Measures. The results of analyses of the rate of firing performance measures (time to fire first round, time to first hit, and rounds to first hit) are presented in Appendix J, Volume II. Mns and SDs from these analyses are presented in Appendix K, Volume II. Figures showing the analysis results are provided in Appendix L, Volume II. These results indicate that the ROTC shooters tended to fire sooner, take less time to make their first hit and fired more rounds to make their first hit. In general their behavior was very much like that of the U.S. Army infantrymen in the TB.

HUMAN FACTORS QUESTIONNAIRE

Following the completion of all phases of the Parametric and Training Experiments, the shooters responded to a human factors questionnaire. This instrument was designed to assess the shooters' perception about the operation of the TB rifle compared to an actual M16A1 rifle; the similarity of firing positions and aiming in the TB and field; the similarity of TB recoil and noise to that produced by an actual rifle; the similarity/comparability of the TB and field visually; and the performance adequacy of the zeroing, self-paced, and target scenario tasks. Table 15 summarizes the response scales used in the questionnaire.

Table 16 summarizes the responses of the Alpha and Bravo group shooters by questionnaire item. Only two of the TB simulation dimensions evaluated were not perceived as similar to the field: rifle recoil and rifle noise. All other dimensions assessed were generally perceived as similar to very similar, good to very good, or about the same in comparisons between the TB and field.

Table 17 summarizes the response of the ROTC group shooters to the questionnaire items. Their responses match those of the Alpha and Bravo group shooters. With the exception of recoil and noise, all other TB simulation dimensions evaluated compared favorably with the field.

The conclusion to be reached from these analyses is that the TB rifle simulation was perceived as very comparable to the real world during the Parametric and Training experiments with two exceptions, rifle recoil and rifle noise.

TABLE 15

Scales Used In Human Factors Questionnaire

Scale	Description				
A	5	4	3	2	1
	Very Similar	Similar	Borderline	Different	Very Different
B	5	4	3	2	1
	Very Good	Good	Borderline	Poor	Very Poor
C	5	4	3	2	1
	Much Better	Better	About the Same	Worse	Much Worse
D	5	4	3	2	1
	Much More	More	About the Same	Less	Much Less
E	5	4	3	2	1
	Much Less	Less	About the Same	More	Much More

TABLE 16

Summary Of Alpha and Bravo Group's Responses To The Human Factors Questionnaire

Questionnaire Item's Focus	Item No.	Scale	Alpha Group (N=15)		Bravo Group (N=14)	
			Mn	SD	Mn	SD
Test Bed Rifle Compared to M16A1						
Similarity of Operating Charging Handle	1	A	3.47	1.19	3.40	1.26
Similarity of Operating Selector Switch	2	A	4.60	0.63	4.79	0.43
Similarity of Trigger Operation	5	A	4.20	0.86	4.00	1.18
Similarity of Trigger Pressure to Squeeze Trigger	6	A	3.80	1.27	3.57	1.28
Similarity of Front Sight Adjustment	7	A	4.36	1.03	4.77	0.44
Similarity of Rear Sight Adjustment	8	A	4.58	0.67	4.69	0.48
Similarity of Magazine Loading	3	A	4.53	0.52	4.71	0.47
Similarity of Magazine Unloading	4	A	4.47	0.64	4.57	0.86
Firing Position and Aiming in Testbed vs Field						
Similarity Obtaining a Good Stock Weld	9	A	4.33	0.82	4.36	1.08
Similarity Assuming the Standing Semisupported Position	10	A	3.53	1.36	4.36	0.93
Similarity of Placing Front Sight Post on Target	13	A	4.40	1.06	4.69	0.48
Recoil						
Similarity of Amount of Recoil Produced by Test Bed Rifle	11	A	2.13	1.06	1.79	1.05
Noise						
Similarity of Noise Level Produced by Test Bed Rifle	12	A	2.33	1.29	2.43	1.22
Targets and Lighting in the Tesbed and Field						
Comparability of Test Bed and Field Targets' Contrast	18	B	4.00	0.93	3.79	0.98
Adequacy of Test Bed Lighting	20	B	4.13	0.74	4.14	0.95
Comparability of Testbed and Field Targets' Size	19	B	3.73	0.96	3.79	0.98
Similarity of Seeing Test Bed and Real Static Targets	14	A	3.13	1.30	3.85	1.27
Similarity of Seeing Test Bed and Real Moving Targets	16	A	3.60	1.30	4.15	0.80
Similarity of Hitting Test Bed and Real Static Targets	15	A	3.60	0.99	4.08	1.19
Similarity of Hitting Test Bed and Real Moving Targets	17	A	3.60	1.05	4.23	0.91

TABLE 16

Summary Of Alpha and Bravo Group's Responses To The Human Factors Questionnaire
(Continued)

Questionnaire Item's Focus	Item No.	Scale	Alpha Group (N=15)		Bravo Group (N=14)	
			Mn	SD	Mn	SD
Targets and Lighting in the Test Bed and Field						
Similarity of Test Bed and Real Target Rise Time	21	A	3.93	0.96	4.07	0.73
Similarity of Test Bed and Real Target Fall Time	22	A	3.27	1.33	3.50	1.16
Similarity of Test Bed and Real Target Slow Speed	23	A	4.13	0.83	4.21	0.80
Similarity of Test Bed and Real Target Fast Speed	24	A	3.87	0.91	4.07	0.83
Task Performance in Test Bed and Field						
Adequacy of Zeroing Task	27	B	4.13	0.64	4.64	0.63
Adequacy of Self-paced Task	31	B	4.07	0.96	4.64	0.50
Adequacy of Target Scenario Task	35	B	4.07	0.82	4.08	0.64
Number of Hits Obtained in Test Bed Compared to Field	37	D	3.07	1.00	3.00	0.82
Amount of Time Needed to Fire in Test Bed Compared to Field	38	E	2.71	0.73	3.15	0.99
Similarity of Amount of Lead Given to Moving Targets in Test Bed Compared to Field	39	A	4.21	0.43	4.43	0.51
Rating of Test Bed Zero Performance Compared to Field Zeroing Performance	28	C	3.07	0.80	4.07	1.07
Rating of Test Bed Self-paced Performance Compared to Field Self-paced Performance	32	C	3.40	1.06	4.07	0.92
Rating of Test Bed Target Scenario Performance Compared to Field Target Scenario Performance	36	C	2.93	0.73	3.31	0.85

TABLE 17

Summary Of ROTC Group Responses To The Human Factors Questionnaire

Questionnaire Item's Focus	Item No.	Scale	ROTC Group (N = 9) Mn	SD
Test Bed Rifle Compared to M16A1				
Similarity of Operating Charging Handle	1	A	4.14	1.46
Similarity of Operating Selector Switch	2	A	5.00	0.00
Similarity of Trigger Operation	5	A	4.00	1.22
Similarity of Trigger Pressure to Squeeze Trigger	6	A	4.12	1.13
Similarity of Front Sight Adjustment	7	A	4.86	0.38
Similarity of Rear Sight Adjustment	8	A	5.00	0.00
Similarity of Magazine Loading	3	A	4.44	1.13
Similarity of Magazine Unloading	4	A	4.89	0.33
Firing Position and Aiming in Test Bed vs Field				
Similarity Obtaining a Good Stock Weld	9	A	4.56	0.73
Similarity Assuming the Standing Semisupported Position	10	A	4.00	1.12
Similarity of Placing Front Sight Post on Target	13	A	4.33	1.00
Recoil				
Similarity of Amount of Recoil Produced by Test Bed Rifle	11	A	1.56	1.01
Noise				
Similarity of Noise Level Produced by Test Bed Rifle	12	A	1.22	0.44
Targets and Lighting in the Test Bed and Field				
Comparability of Test Bed and Field Targets' Contrast	18	B	4.12	0.35
Adequacy of Test Bed Lighting	20	B	4.12	0.83
Comparability of Test Bed and Field Targets' Size	19	B	3.89	0.78
Similarity of Seeing Test Bed and Real Static Targets	14	A	3.44	1.01
Similarity of Seeing Test Bed and Real Moving Targets	6	A	4.00	0.87
Similarity of Hitting Test Bed and Real Static Targets	15	A	4.00	1.00
Similarity of Hitting Test Bed and Real Moving Targets	17	A	4.44	1.01

TABLE 17

Summary Of ROTC Group Responses To The Human Factors Questionnaire
(Continued)

Questionnaire Item's Focus	Item No.	Scale	ROTC Group (N = 9) Mn	 SD
Targets and Lighting in the Testbed and Field				
Similarity of Test Bed and Real Target Rise Time	21	A	4.22	0.97
Similarity of Test Bed and Real Target Fall Time	22	A	3.75	1.17
Similarity of Test Bed and Real Target Slow Speed	23	A	4.67	0.50
Similarity of Test Bed and Real Target Fast Speed	24	A	4.44	0.53
Task Performance in Test Bed and Field				
Adequacy of Zeroing Task	27	B	4.67	0.50
Adequacy of Self-paced Task	31	B	4.67	0.50
Adequacy of Target Scenario Task	35	B	4.33	0.50
Number of Hits Obtained in Testbed Compared to Field	37	D	2.89	1.17
Amount of Time Needed to Fire in Test Bed Compared to Field	38	E	2.56	1.01
Similarity of Amount of Lead Given to Moving Targets in Test Bed Compared to Field	39	A	3.75	1.04
Rating of Test Bed Zero Performance Compared to Field Zeroing Performance	28	C	3.56	1.01
Rating of Test Bed Self-paced Performance Compared to Field Self-paced Performance	32	C	3.44	0.73
Rating of Test Bed Target Scenario Performance Compared to Field Target Scenario Performance	36	C	3.00	1.00

DISCUSSION AND CONCLUSIONS

TB RELIABILITY AND VALIDITY

The man/rifle marksmanship performance of U.S. Army infantrymen was determined to be highly variable in the TB and field. The evidence for this was the moderate reliability and low validity coefficients for TB and field performance.

TB performance predicted soldiers' individual live fire performance as well as standard Army Record Fire scores or other tests reported in the literature. Although the correlations among TB, field, and Record Fire performance measures were statistically significant, they were not high because of the high individual variability associated with man/rifle performance.

PARAMETRIC EXPERIMENT

The infantrymen's performance in the TB did not differ statistically from the field for each of the fundamental marksmanship tasks and their primary dependent measures:

- the zeroing task (using number of rounds to zero).
- the self-paced task (using SD of aiming accuracy).
- the day defense scenario (using the number of targets engaged and overall hit probability, i.e., proportion of targets hit versus targets presented).

Statistically significant differences were found between the TB and field only for dependent measures derived from the product of increased firing rate. These differences included

- A greater number of rounds were fired in the TB than in the field.
- First round hit probability was lower in the TB than in the field.
- More rounds were needed to obtain a first hit in the TB than in the field.
- Less time was needed to fire the first round and obtain the first hit in the TB than in the field.

Recoil and noise in the TB and field were reported as different on the human factors questionnaire. There were no differences in any of the other questionnaire items evaluating the firing experience.

Apparently, shooters adopted the strategy of firing more rounds at a higher rate in the TB than in the field. This was most likely because the TB recoil simulation produced a smaller muzzle deflection than is characteristic of live fire.

This conclusion derives from the following reasoning:

- The recoil impulse in the TB rifle was an upward force that resulted from the asymmetric release of pressurized air in a downward direction at the rifle muzzle.
- If this impulse did not cause the rifle line of sight to deflect from the point of aim to the same degree as live fire then the reaiming process at the end of each shot in the TB would have been shortened or not required at all.
- The result would have been the ability to fire faster and thus more often. This is of course what happened with firing in the TB. It also happened with personnel trained in the TB to shoot the M16A1 rifle when they later exercised their marksmanship skills in the field.

Detailed analyses showed that the TB exhibited all of the fundamental functional relationships characteristic of man/rifle performance and normally obtained in the field. These were a decline in hit probability (overall and first round) as a function of target range, exposure time, and speed.

Because TB and field performance were similar and did not differ statistically on the primary dependent measures for the fundamental marksmanship tasks, we concluded that the TB is a valid research tool to determine the training system requirements for future direct fire weapons systems.

TRAINING EXPERIMENT

The ROTC students' live fire performance did not differ statistically from the infantrymen's performance for each of the fundamental marksmanship tasks and their primary dependent measures:

- The zeroing task (using number of rounds to zero).
- The self-paced task (using SD of aiming accuracy).
- The day defense scenario (using the number of targets engaged in the field and overall hit probability, i.e. proportion of targets hit vs targets presented.)

The ROTC students performed in the field in much the same way as the infantrymen in the Parametric Experiment performed in the TB. For example, in the field, the students fired more rounds to achieve a first hit. They fired sooner. They had lower first round hit probabilities. The probable basis for these results is that the TB recoil effects were less than that produced by the M16A1 rifle. Because the students were trained with lesser recoil, they expected this in the field and adopted a firing strategy that yielded these results.

It is important to note that the nine ROTC students performed in the field as well as seasoned infantrymen who had completed Basic Combat Training (BCT), Advanced Individualized Training (AIT), annual marksmanship qualification, unit marksmanship training, and a preexperiment Record Fire Course. They did so without firing a single live round of ammunition. In comparison, each soldier fires hundreds of rounds of ammunition in BCT. This suggests that the skills required to perform the primary infantryman rifle task does not require the degree of fidelity and feedback currently employed.

RECOMMENDATIONS

1. Improve the fidelity of the recoil impulse.

2. Conduct parametric experiments to define the limits of man/rifle performance as a function of practice for factors known to affect performance:

   - Firing position
   - Apparent target size
   - Trigger activation
   - Target angular rate
   - Time available to engage a target

   The ultimate goal of the experiments should be to develop a quantitative model of aiming performance as a function of practice. These data can be used as input parameter values for expert knowledge based AI training systems. It will also be used to assess future rifle systems and designs.

3. Because of the cost-effectiveness implications of the finding that the TB-trained ROTC students performed as well in the field as seasoned Army riflemen, conduct an experiment to determine the bandwidth of man/rifle performance as a function of extreme levels of training system fidelity and feedback. The dependent measure should be performance from the standard Army Record Fire Qualification course. Their scores should be compared with the scores of Army soldiers completing the same course during Basic Combat Training (BCT)

REFERENCES

Deese, J. W. (1970). *Intelligence profile in the prediction of psychomotor skills, perseverance, and leadership* (HUMRRO Professional Paper 22-70). Alexandria, VA: Human Resources Research Organization.

Dixon, W. J., M. Brown, L. Engelman, J. Frane, M. Hill, R. Jennrich, J. Toporek, (1985). *BMDP statistical software manual.* Berkeley, CA: University of California Press.

Grubbs, F. E. (1964). *Statistical measures of accuracy for riflemen and missile and missile engineers.* Ann Arbor, MI: Edwards Brothers.

Guilford, J. P. (1956). *Fundamental statistics in psychology and education.* New York, NY: McGraw-Hill Book Company, Inc.

Hodgman, C. D. (1961). *CRC standard mathematical tables.* Cleveland, OH: Chemical Rubber Publishing Company.

Humphreys, L. G., Buxton, C. E., & Taylor, H. R. (1936). Steadiness and rifle marksmanship. *Journal of Applied Psychology*, *20*(6), 680-688.

MacCaslin, E. F., & McGuigan, F. J. (1956). The prediction of rifle marksmanship. *Journal of Applied Psychology*, *40*(5), 341-342.

Marshall, A., Bond G., Shaw B., Purvis E., Fields R., & Piper, A. (1984). *Artificial intelligence / expert system (M16A1 rifle). Proceedings of the 6th Interservice / Industry Training Equipment Conference, Volume I* (pp. 383-388). Washington, DC: National Security and Industrial Association.

Schendel, J. D., Heller, F. H., Finley, D. L., & Hawley, J. K. (1985). Use of weaponeer marksmanship trainer in predicting M16A1 rifle qualification performance. *Human Factors*, *27*(3), 313-325.

Spaeth, R. A. & Dunham, G. C. (1921). The correlation between motor control and rifle shooting. *American Journal of Physiology*, *56*(2), 249-256.

Torre, J. P., Maxey, J. L., & Christou, K. (In press). *Engineering studies of the AI Direct Fire Weapons Research Testbed.* Orlando, FL: Advanced Technology, Inc.

Department of the Army. (1983). *M16A1 rifle and rifle marksmanship.* (Field Manual 23-9, Change 3). Washington, D.C.: Government Printing Office.